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CONTENTS

RECENT ADVANCES IN SCIENCE:

PAGE

Pure Mathematics. By F. Puryer White, M.A., St. John's College, Cambridge 1
Astronomy. By W. M. H. Greaves, M.A., Royal Observatory, Greenwich 7
Meteorology. By E. V. Newnham, B.Sc., Meteorological Office, London 12
Physics. By James Rice, M.A., University, Liverpool 16
Biochemistry. By R. Keith Cannan, M.Sc., University College, London 26
Physical Chemistry. By W. E. Garner, M.Sc., University College, London 31
Geology. By G. W. Tyrrell, F.G.S., A.R.C.Sc., Ph.D., University, Glasgow 36
Plant Physiology. By Prof. W. Stiles, Sc.D., University College, Reading. (Plant Physiology Committee). 44

ARTICLES:

THE MEASUREMENT OF SOLIDITY 50
John Innes.

HYDROGEN ION CONCENTRATION AND GROWTH . . . 58
W. H. Pearsall, D.Sc., F L.S., University, Leeds.

THE MAGNIFICATION OF ACOUSTIC VIBRATIONS BY SINGLE AND DOUBLE RESONANCE 68
E. T. Paris, D.Sc., F Inst.P., Signals Experimental Establishment, Woolwich.

SOME REMARKS ON THE CONCEPTION OF INDIVIDUALITY IN BIOLOGY 83
Edward Philpott Mumford, B.Sc., Christ's College, Cambridge.

SOIL INSECTS 92
Prof. A. E. Cameron, M.A., D.Sc., M.Sc., University, Saskatchewan.

POPULAR SCIENCE:

EDUCATION IN ANCIENT EGYPT 109
Warren R. Dawson .

NOTES:

Government and Research 120
The Industrial Institute 120
The Practical Application of the Sciences 122
The Flare-phenomenon in Smallpox (R. R.) 122
Medical Councils 123
The Religion of a Darwinist (R. R.) 123
Spurious Evidence 124
Forms of Equilibrium of Fluid Masses (W. E. Crowther) 125
Notes and News 126

ESSAYS: PAGE

One Hundred Years of Agricultural Science (G. E. Fussell) 134
Sanderson at Oundle and Preparatory Education (V. Seymour Bryant) . 138

ESSAY-REVIEWS:

The Contribution of America to Geological Science. By G. W. Tyrrell, A.R.C.Sc., Ph.D. (being a review of *The First Hundred Years of American Geology*, by G. P. Merrill) 146
William Osler: Some Personal Notes. By Sir Ronald Ross (being a review of *The Life of Sir William Osler*, by Harvey Cushing) 150

REVIEWS:

Relativity and Common Sense. By F. M. Denton 153
Quatre Conférences sur la Théorie de la Relativité. Par A. Einstein . . 153
Production and Measurement of Low Pressures. By F. H. Newman . . 154
Physico-chemical Evolution. By C. E. Guye 155
Physical Chemistry for Students of Medicine. By A. Findlay . . . 155
Regeneration. By J. Loeb 155
Book of Knowledge acquired Concerning the Cultivation of Gold. By Abu'l-Quâsim Muhammad ibn Ahmad al-'Irâqi 156
The "Chemical Age" Chemical Dictionary 157
Synthetic Organic Compounds. By S. P. Schotz 157
A Textbook of General Botany. By G. M. Smith and others . . . 158
A Textbook of General Botany. By R. M. Holman and W. W. Robbins . 158
Plant Life on East Anglian Heaths. By E. P. Farrow 159
Organic Adaptation to Environment. By M. R. Thorpe. 160
Plant Anatomy. By W. C. Stevens 161
Outlines of Economic Zoology. By A. M. Reese 162
The Internal Secretions of the Sex Glands. By A. Lipschütz . . . 163
A General Text of Entomology. By A. D. Imms 164
Animals in the Making. By J. A. Dell 165
Marine Structures. By W. G. Atwood and A. A. Johnson 165
An Introduction to the Study of Recent Corals. By S. J. Hickson . . 166
Lamarck-Darwinism and Dental Disease. By O. Starr 167
Genetics and Eugenics. By W. E. Castle 168
Fossil Man in Spain. By H. Obermaier. 169
The Races of Man and their Distribution. By A. C. Haddon 171
The Home of an Eastern Clan. By L. Milne 172
Primitive Law. By E. S. Hartland 173
Far Away up the Nile. By J. G. Millais 174
On the Edge of the Primeval Forest. By A. Schweitzer 174
Climatic Laws. By S. S. Visher 175
Spectroscopy. By E. C. C. Baly 176
Mathematical Analysis of Statistics. By C. H. Forsyth 176
Studies in Human Biology. By R. Pearl 177
North America. By L. L. R. Jones and P. W. Bryan 177
In Southern Seas. By W. R. Smith 178
Physique and Character. By E. Kretschmer 179

Books Received 180

CONTENTS

PAGE

RECENT ADVANCES IN SCIENCE:

Pure Mathematics. By F. Puryer White, M.A., St. John's College, Cambridge . . . 189
Astronomy. By W. M. H. Greaves, M.A., Royal Observatory, Greenwich 195
Physics. By L. F. Bates, B.Sc., Ph.D., University College, London . 201
Organic Chemistry. By O. L. Brady, D.Sc., F.I.C., University College, London . . . 205
Geology. By G. W. Tyrrell, F.G.S., A.R.C.Sc., Ph.D., University, Glasgow 211
Botany. By E. J. Salisbury, D.Sc., F.L.S., University College, London . 217
Zoology. By R. J. Ludford, Ph.D., B.Sc., University College, London . 221
Entomology. By J. Davidson, D.Sc., Rothamsted Experimental Station, Harpenden . . . 225
Physiology of Reproduction. By John Hammond, M.A., School of Agriculture, Cambridge . . . 232
Education. By A. E. Heath, M.A., University, Liverpool . . . 237

ARTICLES:

THE DIGESTION OF CELLULOSE BY INVERTEBRATES . . 242
C. M. Yonge, Ph.D., B.Sc.
COLOUR AND OTHER CHANGES IN THE FLAKED SURFACES OF FLINT . . . 249
J. Reid Moir, F.G.S., F.R.A.I.
THE SCIENTIFIC VALUE OF COLOUR IN INDUSTRY . . 256
W. G. Raffé, A.R.C.A., Fellow, Institute of British Decorators, London.
THE THIRST OF MAN . . . 268
André L. Simon.

POPULAR SCIENCE:

THE NORMAN BRIDGE LABORATORY OF PHYSICS: ITS EQUIPMENT AND WORK . . . 273
E. C. Watson, Associate Prof. Physics, Institute of Technology, Pasadena, California, U.S.A.

NOTES:

Dr. Gye and Cancer. (J. E. McCartney, M.D D.Sc.) . . . 284
The Originators of Aviation and of Wireless . . . 285
Modern Miracles . . . 285
A New Kind of Maiden Speech . . . 285
Scientific Periodicals . . . 286
On All-fours . . . 287
The Industrial Institute . . . 288
Notes and News . . . 288

ESSAYS:

The Animate Model of Physical Process (Joshua C. Gregory, B.Sc.) . . 298
Some Czech Contributions to Chemical Science (J. G. F. Druce, M.Sc., F.I.C.) . . . 308
The Mosquito-theory of Malaria and the late Prof. G. B. Grassi (Sir R. Ross) . . . 311

PAGE

ESSAY-REVIEWS:

Are the Continents Adrift ?. By G. W. Tyrrell, A.R.C.Sc., Ph.D. (being a Review of "The Origin of Continents and Oceans," by A. Wegener) 321
The Borders of Biology: Modern Views on Life and Mind. By J. H. Woodger (being a Review of "Living Organisms," by E. S. Goodrich) 326
The Physics of Evolution. By β_2 (being a Review of "The Elements of Physical Biology," by Alfred J. Lotka) 337

REVIEWS:

History of Mathematics. By D. E. Smith 340
Notations et Formules Vectorielles. By A. Lafay 342
Elements of the Mathematical Theory of Limits. By J. G. Leathem . 343
Conformal Representation. By L. Lewent 344
An Introduction to Mathematical Probability. By J. L. Coolidge . . 344
Lectures on Cauchy's Problem. By J. Hadamard 345
Atoms and Rays. By Sir Oliver Lodge 348
The Structure of Crystals. By R. W. G. Wyckoff 349
Intermediate Light. By R. A. Houstoun 350
A Treatise on Electricity. By F. B. Pidduck 350
L'Origine Tourbillonnaire de l'Atome. By J. V. D'Ainvelle . . . 351
Isotopes. By F. W. Aston 351
The Foundations of Colloid Chemistry. By E. Hatschek 352
A History of Bleaching. By S. H. Higgins 352
Premier Conseil de Chimie Tenu à Bruxells, 1922 352
Physical Chemistry. By J. C. Philip 353
Modern Inorganic Chemistry. By J. W. Mellor 354
The Anthocyanin Pigments of Plants. By M. W. Onslow 354
Chemistry to the Time of Dalton. By E. J. Holmyard 355
The Constituents of Coal Tar. By P. E. Spielmann 355
Bituminous Substances. By P. E. Spielmann 355
The Face of the Earth. By E. Suess 356
Handbook of the Geology of Ireland. By G. A. J. Cole 356
Plant Forms and their Evolution in South Africa. By J. W. Bews . . 357
Œcology of Plants. By E. Warming 357
Plants and Man. By F. O. Bower 358
The Romance of the Fungus World. By R. T. Rolfe and F. W. Rolfe . 358
Outlines of General Zoology. By H. H. Newman 359
British Birds. By A. Thorburn 360
Birds of America. By T. G. Pearson 361
Anatomy and Physiology of the Honey Bee. By R. E. Snodgrass . . 362
Rejuvenating by Grafting. By S. Voronoff 362
Internal Secretion and the Ductless Glands. By S. Vincent 362
A Textbook of Physiology. By H. E. Roaf 363
An Introduction to Recent Advances in Comparative Physiology. By L. T. Hogben 364
The Great Plague in London in 1665. By W. G. Bell 364
Small Electric Generating Sets. By W. Wilson 365
Industrial Electricity. By C. L. Dawes 365
Radio: Beam and Broadcast. By A. H. Morse 365
Electrical Engineering. By L. A. Hazeltine 366
Magnets. By C. R. Underhill 367
The Metaphysical Foundations of Modern Science. By E. A. Burt . . 367
The Isles of Wisdom. By A. Moszkowski 368
Problems of Personality. By M. Prince. 368
Airs for the Hautbois and other Instruments. By E. N. da C. Andrade . 369
The Growth of the Mind. By K. Koffka 369
Studies in the History of Mediæval Science. By C. H. Haskins . . 370
The Mechanical Investigations of Leonardo da Vinci. By I. B. Hart . 370
Scientific Method. By F. W. Westaway 371

BOOKS RECEIVED 372

CONTENTS

PAGE

RECENT ADVANCES IN SCIENCE:

Pure Mathematics. By F. Puryer White, M.A., St. John's College, Cambridge 377
Meteorology. By E. V. Newnham, B.Sc., Meteorological Office, London 385
Physics. By L. F. Bates, B.Sc., Ph.D., F.Inst.P., University College, London 392
Physical Chemistry. By W. E. Garner, M.Sc., University College, London 400
Biochemistry. By R. Keith Cannan, M Sc., University College, London . 405
Geology. By G. W. Tyrrell, F.G.S., A.R.C.Sc., Ph.D., University, Glasgow 408
Plant Physiology. By Prof. W. Stiles, Sc.D., University College, Reading. (Plant Physiology Committee). 417
Pedology. By G. W. Robinson, M.A., University College of North Wales, Bangor 423
Animal Nutrition. By H. E. Woodman, Ph.D., D.Sc., School of Agriculture, Cambridge 429

ARTICLES:

WHEN CERTAIN MATHEMATICAL FORMULAS BECAME TRUE 436
Prof. G A. Miller, M.A., Ph.D., University, Illinois, U.S.A.

OBSERVATIONS OF SYSTEMATIC MOVEMENTS WITHIN THE SUN 439
H. W. Newton, F.R.A.S., Royal Observatory, Greenwich

THE X-RAY ANALYSIS OF ORGANIC COMPOUNDS 450
G. Shearer, M.A., Ph.D., The Royal Institution, London

THE RECAPITULATION THEORY 461
Prof. E. W. MacBride, F.R.S., Imperial College of Science and Technology, London

EVOLUTION IN SPIDERS 475
T. H. Savory, B.A.

THE IMPORTANCE OF MOSQUITO-CONTROL 481
Sir Ronald Ross, K.C.B., K.C.M.G., F.R.S.

POPULAR SCIENCE:

THE POST-ROMAN HISTORY OF THE RHONE DELTA . . 487
R. D. Oldham, F.R.S.

NOTES:

Personal Recollections. (Sir A. E. Shipley, G.B.E., F.R.S.) 497
Physiology, Pathology, and Epidemiology 500
Information-Bureaux Conference 501
Notes and News 503

PAGE

CORRESPONDENCE:

Are the Continents Adrift? (G. W. Tyrrell, F.G.S., A.R.C.Sc., Ph.D.) . 512

ESSAYS:

The Encouragement of Medical Discovery—A Summary. (Sir Ronald Ross) 513

ESSAY-REVIEWS:

The Progress of London Geology. By S. W. Wooldridge, M.Sc., F.G.S. (being a Review of "Maps and Memoirs on the London District," published by H.M. Geological Survey, 1915–1925) 517
The Psychology of Indian Unrest. By Col. W. G. King, C.I.E., D.P.H., I.M.S. (ret.) (being a Review of "The Heart of Âryavârta," by the Earl of Ronaldshay) 523
Intelligence of Chimpanzees. By Prof. J. A. Thomson (being a Review of "The Mentality of Apes," by W. Köhler, and "Chimpanzee Intelligence," by R. M. Yerkes and B. W. Learned 533

REVIEWS:

Summation of Series. By L. B. W. Jolley 535
Four-Figure Mathematical Tables. By G. W. C. Kaye and T. H. Laby . 535
Handbuch der Radiologie. By M. v. Laue and others 535
A Treatise on Light. By R. A Houstoun 536
The Spectroscopy of X-Rays. By M. Siegbahn 537
Le Principe de Symétrie et ses Applications. By F. M. Jaeger . . . 538
Electricity and the Structure of Matter. By L. Southerns . . . 539
An Introduction to the Chemistry of Radio-active Substances. By A. S. Russell 539
Useful Aspects of Geology. By S. J. Shand 540
Coal and Civilisation. By E. C. Jeffrey 541
A Textbook of General Botany. By W. H. Brown 541
The Vegetation of Burma from an Ecological Standpoint. By L. D. Stamp 542
Genetics in Plant and Animal Improvement. By D. F. Jones . . . 543
Evolution in the Light of Modern Knowledge. A Collective Work . . 543
Concerning Evolution. By J. A. Thomson 545
Evolution, Heredity, and Variation. By D. W. Cutler 546
Health and Environment. By L. Hill 546
Lister and his Achievement. By Sir W. W. Cheyne 548
The Bacteriology of Food. By C. Dukes 548
Medical Education. By A. Flexner 549
The Engines of the Human Body. By Sir A. Keith 550
Medical Sciences in the German Universities. By T. Billroth . . . 550
Structural Engineering. By G. F. Swain 551
Oscillographs. By J. T. Irwin 552
Choosing your Life-work. By W. Rosengarten 552
Civilisation and Climate. By E. Huntingdon 552
Historic Instruments for the Advancement of Science. By R. T. Gunther 553
An Introduction to Economic Geography. By W. D. Jones and D. S. Whittlesey 554
Life after Death in Oceania and the Malay Archipelago. By R. Moss . 554
The Science and Art of Living. By L. Williams 555
Why the Weather? By C. F. Brooks 556
Education in East Africa. Educational Commission to East Africa . 556

Books Received 557

CONTENTS

RECENT ADVANCES IN SCIENCE: PAGE

ASTRONOMY. By W. M. H. Greaves, M.A., Royal Observatory, Greenwich . . . 565

PHYSICS. By L. F. Bates, B.Sc., Ph.D., F.Inst.P., University College, London . . . 568

GEOLOGY. By G. W. Tyrrell, F.G.S., A.R.C.Sc., Ph.D., University, Glasgow . . . 577

PREHISTORIC ARCHÆOLOGY. By J. Reid Moir, F.G.S., F.R.A.I. . . . 586

BOTANY. By E. J. Salisbury, D.Sc., F.L.S., University College, London . 588

ZOOLOGY. By R. J. Ludford, D.Sc., Ph.D., University College, London . 591

ENTOMOLOGY. By J. Davidson, D.Sc., Rothamsted Experimental Station, Harpenden . . . 594

ARTICLES:

THE DETERMINATION OF STELLAR PARALLAX . . . 603
D. L. EDWARDS, A.R.C.S., D.I.C., F.R.A.S., Norman Lockyer Observatory, Sidmouth.

THE PASSAGE OF ELECTRICITY THROUGH DISCHARGE TUBES AT LOW PRESSURE . . . 620
PROF. R. WHIDDINGTON, M.A., D.Sc., F.R.S., University, Leeds.

PARASITISM IN EVOLUTION . . . 637
SIR A. E. SHIPLEY, G.B.E., Sc.D., F.R.S., University, Cambridge.

POPULAR SCIENCE:

THE INDUSTRIAL MEASUREMENT OF COLOUR . . . 662
W. G. RAFFÉ, A.R.C.A., F.R.S.A., F.I.B.D.

NOTES:

Prof. E. W. MacBride, F.R.S. . . . 675
Recent Discoveries in Mammalian Reproductory Physiology . . . 675
The South African Association for the Advancement of Science . . . 676
The Optical Convention for 1926 . . . 677
The American Indian . . . 678
The Prickly Pear in Australia . . . 679
Winter Thunderstorms . . . 679
To Dazzle, or not to Dazzle . . . 680
Motor Tyres and Reclaimed Rubber . . . 680
The Position of Religion and Science in Russia To-day . . . 681
Public Discussions on the Ethics of Birth-control . . . 682
The Harrow School Register . . . 682
A Herdman Scholarship . . . 683
England and Ireland . . . 683
Notes and News . . . 683

ESSAYS:

Dvi-Manganese, The Element of Atomic Number 75 (J. G. F. Druce, M.Sc.) 690
S. T. Coleridge as a Philosophical Biologist (J. Needham, M.A.) . . 692

PAGE

ESSAY-REVIEW:

The Progress of Prehistory. By β_2 (being a review of "Human Origins," by G. G. MacCurdy) 703

REVIEWS:

Differential Equations. By H. B. Phillips 711
Fourier's Theorem and Harmonic Analysis for Physicists and Engineers. By A. Eagle 711
Traité du Calcul des Probabilités et de ses Applications. Par E. Borel . 712
Calcul des Probabilités. Par P. Lévy 712
Cours de Mathématiques Générales. Par G. Verriest 714
Tables and Charts for the Use of Engineers and others. By A. D. Browne 714
Mémorial des Sciences Mathématiques. Par G. Valiron et P. Appell . 714
Practical Astronomy. By G. L. Hosmer 715
Meteors. By C. P. Olivier 715
Photo-Electricity. By H. S. Allen 716
Electric Precipitation. By Sir O. Lodge 717
Modern Magnetics. By F. Auerbach 717
Le mouvement scientifique contemporain en France. Par G. Matisse . 718
Müller-Pouillet's Lehrbuch der Physik. By K. F. Herzfeld . . . 718
The Chemistry of Drugs. By N. Evers 720
Photo-Synthesis. By W. Stiles 720
Volatile Solvents and Thinners. By N. Heaton 721
The Chemistry of Drying Oils. By R. S. Morrell 721
British Chemicals, their Manufacturers and Uses. By the Association of British Chemical Manufacturers 722
Ammonites from the Upper Kimmeridge Clay. By E. Neaverson . . 722
A Class Book of Botany. By E. Stenhouse 723
Monocotyledons. By A. Arber 724
An Introduction to Plant Anatomy. By A. J. Eames 725
Spitsbergen Papers 725
Soil Characteristics. By P. Emerson 726
Principles of Genetics. By E. W. Sinnott and L. C. Dunn 726
The Ascent of Man. By A. Machin 727
Evolution and Genetics. By T. H. Morgan 728
Textbook of Palæontology. By K. A. von Zittel 729
Louis Pasteur. By S. J. Holmes 729
Organic Medicaments and their Preparation. By E. Fourneau . . . 729
The Erythrocite and the Action of Simple Hæmolysins. By E. Ponder . 730
Physiological and Clinical Chemistry. By W. A. Pearson and J. S. Hepburn 730
Food and Health. By R. H. A. Plimmer 731
Mere Mortals. By C. MacLaurin 731
Travel Diary of a Philosopher. By H. Keyserling 732
Matter, Man and Mind. By W. F. F. Shearcroft 733
A Course in Philosophy. By G. P. Conger 733
Statistical Methods for Research Workers. By R. A. Fisher 733
Population. By A. M. Carr-Saunders 734
Genetic Studies of Genius. By L. M. Terman and others 735
Teaching Science in the Schools. By E. R. Downing 736

Books Received 737

Index to Vol. XX (1925–6)

SCIENCE PROGRESS

RECENT ADVANCES IN SCIENCE

PURE MATHEMATICS. By F. PURYER WHITE, M.A., St. John's College, Cambridge.

Theory of Aggregates.—Little work has been done so far with regard to regions of which the connectivity is infinite. In his *Grundzüge der Mengenlehre* (Leipzig, 1914) Hausdorff makes the statement that we can in this case make arbitrarily many successive cross-cuts without dissevering the region G, the resulting regions having still infinite connectivity, and goes on to remark that it would be untrue to say that we can make an infinite number of cross-cuts without dissevering G, for the remaining aggregate need be neither a region nor connected. P. Urysohn (*Math. Zeits.*, **21**, 1924, 133–50) discusses this last statement. It is easy to see by particular examples that Hausdorff's assertion is true in the sense that it has not been proved that we can make an infinite number of cross-cuts without dissevering G, but Urysohn goes further and proves that we can always choose an enumerable aggregate of cross-cuts in such a way that we get a simply-connected region. A much more definite theorem is the following: For any bounded connected plane region G we can find a system (finite in number or an enumerable aggregate) of rectilinear cross-cuts $J_1, J_2 \ldots$, not intersecting, such that $G - \Sigma J_n$ is a simply-connected region. The proof is highly complicated, but that, says the author, " in der Natur der Sache liegt."

Analysis.—In a series of papers dating back to 1911, J. Horn has dealt with the representation of the solutions of linear and non-linear differential and difference equations and of integral equations of the Volterra type as Laplace integrals of the form

$$y = \int_0^\infty v(z) e^{xz} dz.$$

These, which can be expressed asymptotically by divergent power series, can be developed as convergent factorial or gammaquotient series. In the first part of a recent paper (*Math. Zeits.*, **21**, 1924, 85–95) he shows that the integrals can also be developed as convergent binomial-coefficient series (Newton series) of the form

$$\Sigma a_s \binom{x-1}{s}$$

The second part of the paper gives a correction to a previous paper on the development in gammaquotient series. Finally, the author discusses a paper by Garnier (*Liouville*, 1919, 99–200) dealing with the irregular singularities of linear differential equations. Garnier considered a linear differential equation with a place of indetermination $x = \infty$ as the limiting case of an equation with regular singularities which tend to infinity. The substitutions of the group of monodromy thereby pass into the relations between the special integrals, the "rélations de structure." Horn obtains these relations, for the case of a second order equation, by means of the Laplace integrals, and remarks that an alternative method is the method of successive approximations, by means of which he has investigated the behaviour of the integrals in the complete neighbourhood of the irregularity.

A. Besikowitsch (*Math. Zeits.*, **21**, 1924, 111–18) shows that given an arbitrary function $\phi(x)$ with continuous kth derivative we can always find a function $f(x)$ which is analytic for $0 < x < 1$, which has with all its derivatives assigned values for $x = 0$ and $x = 1$, and for which the difference $f(x) - \phi(x)$ and its first k derivatives are arbitrarily small; he thus proves an assertion made by Birkhoff without proof. He is also able to establish a related theorem for analytic functions of a complex variable. The same author, in collaboration with J. Tamarkin (*ibid.*, 119–25), then applies his construction to obtain asymptotic expressions for the integrals of a system of linear differential equations which depend upon a parameter.

V. Kock (*Math. Zeits.*, **21**, 1924, 161–73) obtains the solution of a Volterra integral equation of the second kind of the special form

$$G(x) = F(x) + \int_0^x G(\xi)K(x-\xi)d\xi$$

as a definite integral. He gives examples, one of which had been previously discussed by Whittaker.

The classical problem of the inversion of the definite integral with fixed finite limits; that is, given any kernel $K(s, t)$, to find $g(t)$ so as to satisfy

$$\int_a^b K(s, t)g(t)dt = f(s),\ a \leqslant s, t \leqslant b,$$

when $f(s)$ is given, was indirectly solved by Picard and Lauricella in 1909 by a method which assumed that all adjoint characteristic functions $\phi_m(s)$ and $\psi_m(t)$ of K(s, t) were known explicitly. The consecutive determination of these functions had been shown to be possible by means of Schmidt's iteration process, but the actual carrying through of the work is impracticable, and it seemed desirable to build up another method by applying Schmidt's process directly to the original equation. This was done by Vergerio (1916) and Mollerup (1923), but even here an infinite sequence of consecutively conditioned limit processes of three kinds, iteration, determination of characteristic functions, calculation of Fourier constants, has to be carried out before the conditions for a solution and the minimal solution can be given. In the older literature the existence of a symmetrical inversion formula

$$\int_a^b \mathrm{H}(s, t)\, f(s)\, ds = g(t)$$

was guessed at and sought for, and indeed for infinite limits of integration such inversions (Fourier and Bessel integrals) are well known. C. H. Müntz (*Math. Ann.*, **87**, 1922, 139–49) has recently shown that a resolving kernel H(s, t) only exists if the original kernel K(s, t) can be expressed in the form

$$\mathrm{K}(s, t) = \sum_1^M p_m(s)\, q_m(t),$$

and he reduced to a few lines the solution of the original problem, with the help of the theory of orthogonal systems. He now (*Math. Zeits.*, **21**, 1924, 96–110) shows that the simple iteration process of Vergerio and Mollerup, with the help of orthogonal systems, gives a solution of the problem which is simple and practicable. The same process also gives all the adjoint characteristic functions.

If we have given a system of functions $\mathrm{F}_1(x)$, $\mathrm{F}_2(x)$ . . . and a function F(x), for $a \leqq x \leqq b$, then there arises in the theory of approximations the question whether F can be expressed as a linear aggregate of the form $\sum_1^N a_n^{(N)} \mathrm{F}_n(x)$ with an error of arbitrarily assigned smallness. This is clearly the case for any continuous function F(x) with $\mathrm{F}_n(x) = x^{n-1}$. It may happen that certain partial sequences from among the $\mathrm{F}_n(x)$ are sufficient—for example, for $\mathrm{F}_n(x) = x^{n-1}$, we can take a sequence $1, x^{v_1-1}, x^{v_2-1}$, where $\sum_1^\infty (1/v_v)$ diverges. There are, however, certain systems of functions $\mathrm{F}_n(x)$ such that *any* infinite partial sequence from them is capable of giving thus an approximation to any continuous function, e.g. the Bernoulli polynomials. In general a prescribed system $\mathrm{F}_n(x)$ will be capable of giving approximations only to a certain class of functions F(x); if, then, every function which can be approximated to by all the $F_n(x)$ retains the property for *any* partial system of the $F_n(x)$, the system is called "dense" (*dicht*) by C. H. Müntz, who proves, in the second part of the paper quoted above, that the indefinite integrals $\int_a^s f_n(s)ds$ of the functions $f_n(s)$ obtained by iteration from a given symmetrical kernel and a given function $f_0(s)$, both of whose squares are summable, by the formula

$$f_n(s) = \int_a^b \phi(s, t)\, f_{n-1}(t)\, dt,$$

give such a dense system. The Bernoulli functions are included as a special case.

Algebraic Numbers.—The number-fields $K(\epsilon)$ of the l^s-th and $K(\zeta)$ of the l-th roots of unity differ essentially in their properties according as their *class-numbers, i.e.* the (finite) numbers of ideal-classes, are or are not divisible by the prime number l. In the former case the fields are said to be *irregular*; such fields arise for $l = 37, 59, 67$. Since the time of Kummer irregular fields have several times been treated, notably by E. Hecke and F. Bernstein, who showed that with certain assumptions as to their properties it is possible to prove Fermat's Last Theorem. F. Pollaczek (*Math. Zeits.*, **21**, 1924, 1–38) has recently made a new investigation of the subject, basing himself upon the work of Furtwängler on general number-fields; in particular he deals with the simplest case in which the class-number is divisible by the first power of l only. He examines, in a concluding paragraph, the relation of his results to the assumptions referred to above.

Conformal Representation.—The possibility of representing any simply-connected polygon upon the unit circle by means of the Schwarz-Christoffel formula was first proved by means of an appeal to the general theorem of Riemann on conformal representation. Later Schläfli, Phragmén, and Bieberbach gave direct proofs by the method of continuity. The formula

$$z = M \int_0^\zeta (1 - \zeta/\zeta_1)^{-\beta_1} \ldots (1 - \zeta/\zeta_n)^{-\beta_n} d\zeta,$$

with $M > O,\ \zeta_h = e^{\sigma_h},\ |\beta_h| < 1$ and $\Sigma\beta_h = 2$,

represents the unit circle of the $\zeta\ (= \rho e^{i\sigma})$-plane upon a polygon of n sides with exterior angles $\beta_1 \pi, \ldots \beta_n\pi$, which contains the point $z = o$ in its interior. We have to show that this formula, by suitable choice of the parameters M, σ, β, can give any simple polygon containing the origin. The aggregate of polygons P_s (not necessarily simple) given by the formula is a connected $2n$-dimensional manifold K_s. The aggregate of simple polygons P enclosing the origin is likewise a $2n$-dimensional manifold K. We have to show that to every "point" P of K there corresponds a "point" P_1 of K_1. First we prove that the manifold K is connected. Then we consider a point P°_1 of K_1 for which all $\beta_i > o$; to it corresponds certainly a point P° of K, since the formula in this case gives a convex and therefore simple polygon. Join P° to P by a continuous curve L in K; we have to show that by continuous variation of the co-ordinates of P°_1 we can find a point in K_1 corresponding to each point of L. The first step of the proof of the "neighbourhood" theorem (*Umgebungssatz*), that if to a point P on L there corresponds a point P_1 of K_1, the same is true for a complete neighbourhood of P. Bieberbach proved this by means of a theorem of Brouwer in Analysis Situs; Schläfli reduced it to the theorem that a certain functional determinant does not vanish, and proved this by a complicated calculation; A. Weinstein (*Math. Zeits.*, **21**, 1924, 72–84), the latest writer on the subject, whose aim is to give a completely elementary proof of the original theorem, proves Schläfli's theorem in a much simpler manner. We have next to show that as we go along L no "threshold" (*Schwelle*) P′ occurs, such that only the P on L which precede P′ have corresponding points in K_1, and P′ itself does not. Bieberbach deduced this from general results of Caratheodory on the convergence of sequences of functions, but Weinstein prefers to follow Phragmén, who completed the work of Schläfli, and prove first an intermediate theorem, which establishes bounds for the values of the co-ordinates of the point P_1 corresponding to a point P on L. He points out that Phragmén's proof is only valid for convex polygons, and supplies the deficiency. The final result then follows without difficulty.

Continuous Groups.—The calculation of the differential invariants of a continuous transformation group in two (non-homogeneous) variables, as undertaken by Lie, requires the integration of complete systems of differential equations and is a matter of great labour and complication. G. Kowalewski (*Math. Zeits.*, **21**, 1924, 39–44) has now shown how in many cases this can be avoided and the results obtained without any integration. The centre point of the method is a theorem whereby, given an invariant arc-element, an invariant surface-element, and an invariant differential equation of higher order than the first, we can at once write down a differential invariant, which in certain cases must in fact be a constant. Thus for the general linear group G_6, the differential equations of the straight line, $y_2 = O$, and of the parabola, $(y_2^{-2/3})'' = O$, are invariant, and the fundamental theorem leads at once to the formulæ

$$y_2 \Omega \omega^{-3} = 1, \quad y_2^{5/3} (y_2^{-2/3})'' \; \Omega \omega^{-5} = 1,$$

where ωdx is an invariant arc-element and $\Omega(dx\delta y - dy\delta x)$ an invariant surface-element, both of less than the 5th order. These determine Ω and ω, and a second application of the theorem, using the invariant differential equation of the conic, $(y_2^{-2/3})''' = 0$, leads at once to the lowest differential invariant,

$$y_2^{-1/3}\,(y_2^{-2/3})''^{\,-3/2}\,(y_2^{-2/3})'''.$$

Automorphic Functions.—The theory of automorphic functions depends upon the discontinuous groups of one-one transformations, the functions being invariants of the groups. For one complex variable the linear transformations $x' = (ax + b)/(cx+d)$ are the only birational transformations, but for several variables there are birational transformations of any order, the Cremona transformations. Hence the first step in the theory of automorphic functions of several variables is the investigation of discontinuous groups of Cremona transformations. The whole of such transformations of a space R_n forms a continuous group; this contains certain continuous subgroups depending upon a finite number of parameters. We can consider such finite, continuous Cremona groups as a first generalisation of the collineation group, the simplest special case, and in the first instance we may confine ourselves to their sub-groups. In the plane the finite, continuous Cremona groups are all known; they are (1) the 8-parameter collineation group, (2) the 6-parameter group of quadratic transformations with two fixed base points, (3) the $(n + 5)$-parameter Jonquières group of transformations of order n, which leave invariant a pencil of lines and a linear system of curves of any order which have the centre of the pencil for a common $(n - 1)$-ple point and have common tangents there. Among the discontinuous groups of (1) are the group of the Abelian functions and the hyperfuchsian group of linear substitutions (discovered by Picard) which leave an indefinite Hermitian form invariant. The discontinuous groups of (2) can be transformed into the group of direct circular transformations (*Kreisverwandtschaften*) or the hyperabelian group, the theory of which is likewise due to Picard. P. J. Myrberg (*Math. Zeits.*, **21**, 1924, 224–53), in a very readable and interesting paper, sets himself to investigate discontinuous Jonquières groups, and thus to write a first chapter on automorphic functions of two variables. By suitable choice of non-homogeneous co-ordinates the general transformation of the Jonquières group can be written

$$x' = \frac{ax+b}{cx+d},\; y' = \frac{k_0y + k_1x^n + k_2x^{n-1} + \ldots + k_{n+1}}{(cx+d)^n}$$

and contains $(n + 5)$ essential parameters. For $n = 1$, we get the linear transformation

$$x' = \frac{ax+b}{cx+d},\; y' = \frac{k_0y + k_1x + k_2}{cx+d}$$

The simplest example of a discontinuous group of this kind is the group $u' = u + h\omega_1 + m\omega_2$, $\omega_1' = a\omega_1 + b\omega_2$, $\omega_2' = c\omega_1 + d\omega_2$ of the doubly-periodic functions of u with periods ω_1, ω_2, in which the coefficients take all integral values satisfying the condition $ad - bc = 1$. Every elliptic function considered as a function of u, ω_1, ω_2 is an automorphic form of the group, and the forms of zero dimensions are automorphic functions of the non-homogeneous group

$$x' = \frac{ax + b}{cx + d}, y' = \frac{y + lx + m}{cx + d}$$

Those of the forms which are independent of y reduce to modular functions. Now instead of the modular group we can take in the complex plane any essentially discontinuous group of linear substitutions and obtain a corresponding ternary collineation group and a general Jonquières group. We thus get a class of automorphic functions which is related in an interesting way to the automorphic functions of one variable. Using these functions, for example, we can, for certain classes of linear differential equations, express the inverse functions of the integral quotients as single-valued functions and thus solve the inversion problem whose solution for homogeneous linear differential equations of the second order is given by the automorphic functions of one complex variable.

Differential Geometry.—W. Blaschke (*Math. Zeits.*, **21**, 1924, 209–10) proves that the only system of curves on a sphere which possess the following three properties—(1) the curves are differentiable, closed, and have no double points, (2) one and only one curve of the system passes through three points of the sphere, (3) any two curves of the system which intersect do so at equal angles at the two points of intersection—consists of the plane sections, *i.e.* of circles.

ASTRONOMY.

By W. M. H. GREAVES, M.A., Royal Observatory, Greenwich.

Effective Temperatures of Stars.—In the *Royal Astronomical Society's Monthly Notices* for March 1925, R. A. Sampson gives an account of the spectrophotometric work which has been carried out recently at Edinburgh. The effective temperature of a star may be defined as that temperature at which a " black body " will emit luminosity whose intensity-distribution in the spectrum agrees most closely with the intensity-distribution of the light from the star in question. Consequently, in order to obtain a star's effective temperature it is necessary in some way or other to measure the relative intensities in different spectral regions of the light emitted by the star. The problem is complicated by the absorbtion lines in the star's spectrum; it is necessary to obtain the intensity distribution which would manifest itself if these lines were not present. In other words, the measured spectrum must be "smoothed."

In obtaining the spectra the Edinburgh observers used an objective prism of 12° angle in front of a 6-in. photovisual object glass giving a sharp focus from (B) to (K) with a dispersion over all of 1 mm. = 121 angstrom units. Photographs of the spectra of stars were obtained with this instrument, and the problem of measurement became one of measuring the density of photographic deposit in different spectral regions, and then converting these measures into measures of light-intensity. The photographic densities were measured with a Koch microphotometer. In this instrument, a description of which is to be found in *Monthly Notices R.A.S.* vol. 83, no. 3, pp. 174 et seq., the spectral plate under examination was moved past a slit through which a beam from a source of light fell on it, and after passing through the photographic deposit was incident on the sensitive surface of a photo-electric cell. A second beam from the same source fell on the sensitive surface of a second cell. The two cells were connected in series with a battery, and as the spectral plate moved past the slit, the electric charge on the connection between the grid of the first cell and the sensitive surface of the second was subject to variation, and these variations were registered by a string electrometer, which was fitted with a projection apparatus for projecting a spot of light on to the surface of a moving photographic film. In this way a trace was obtained showing (after calibration) a plot of density of photographic deposit against wave-length. The absorbtion lines were smoothed out by drawing a pencil curve through the peaks of the trace and the ordinates were then measured for definite wave-lengths.

It remains to convert the measures into measures of light intensity. In order to do this, experimental exposures were made for the same time and for ascertained ratios of intensity, and these exposures give the necessary data. It should be mentioned that all the exposures were made on standard plates, with standard conditions of development and exposure. Actually, the process, which is fully explained by Prof. Sampson, gives for any wave-length the ratio of the light-intensities of two stars on the same plate. It is necessary to adopt some definite star as standard, and Polaris was actually adopted, the spectra of other stars being compared with that of Polaris.

The procedure was now as follows. Denoting by I_λ and I'_λ the spectral intensities for wave-length λ of a star and of Polaris, the measures gave the ratios I_λ/I'_λ for various values of λ. Assuming an effective temperature 6500° for Polaris, we can calculate by Planck's black-body formula the ratio $I'_{\lambda_1}/I'_{\lambda_2}$ for any two wave-lengths λ_1, λ_2. We then get the ratio $I\lambda_1/I\lambda_2$. In other words, the comparison with Polaris yields measures of the relative intensities I_λ of the star for different wave-lengths λ. The temperature at which these values most closely fit the black-body formula is, after suitable corrections, the effective temperature of the star.

The most important correction is that for the effect of atmospheric absorbtion. If the star and Polaris were photographed at the same altitude, we would expect the value obtained for the effective temperature in the manner explained above to be correct, save for accidental error, but if the star were photographed at a low altitude, the effect of relative absorbtion of the atmosphere would make it appear too red and the deduced temperature would be too low. Prof. Sampson gives a formula which was used to correct the measures. This formula was obtained by comparing the results for different altitudes. A further correction was one to the black-body formula itself, expressing the departure of stellar radiation from the ideal conditions of black-body radiation. This is a well-known phenomenon in the case of the sun, and Prof. Sampson assumes that the correcting factor is the same for stars as it is for the sun.

In obtaining the best fit of the observations of a star to the (corrected) black-body formula, Prof. Sampson's procedure is effectively as follows. The measured values I_λ of the intensity of radiation for wave-length λ are plotted as ordinates against $1/\lambda$ as abscissa, and the straight line of closest fit is drawn through the plotted points. The slope of this line is a measure of the reciprocal of the temperature. In the majority of cases the straight lines fit the points very well, but there are exceptional cases in which the fit is not good. For instance, the plotted points in the case of γ Cassiopeia, a star of spectral type Bop, appear to lie not on one, but on two intersecting straight lines.

The effective temperatures of 64 stars are given in the paper. A study is made of the connection between effective temperature and spectral type. A study is also made of the observations of δ Cephii.

It was mentioned above that the adopted effective temperature of Polaris was 6500°. This figure was obtained by a series of comparisons between Polaris and Capella, an effective temperature of 5500° being adopted for Capella.

Another series of determinations of effective temperature is given by C. G. Abbott in the *Astrophysical Journal* for September 1924, pp. 87 to 107. Abbott's procedure is entirely different from Sampson's. The observations were made with the 100-inch telescope at Mount Wilson, and the light from the star fell upon a plane mirror at the focus of the telescope, and thence was made to pass through an optical train, including a 60° flint-glass prism, on to the vanes of a radiometer. By rotating the prism, light of any required wave-length between 0·437 μ and 2·224 μ could be made to fall on the radiometer vane, and the resulting deflection of the radiometer suspension measured the intensity of the light of the wave-length in question. Besides stellar observations, observations were also made of the sun. In this case the sun's light was reduced by suitable appliances, the reduction of the solar beam as compared with the stellar beams being approximately $0{\cdot}89 \times 10^{10}$. Corrections for atmospheric absorbtion were made from data previously determined in the course of solar work, and the energy distributions outside the atmosphere were thus deduced. The data were supplemented for the shorter wave-lengths from the spectro-photometric results of Wilsing Scheiner Munch, Rosenberg, and Plaskett.

The resulting data range from wave-length 0·38 to wave-length 2·22 μ, and Abbott gives a diagram comparing them with the black-body curves of closest fit. The agreement is fairly good, but there are exceptions. In the case of Vega, for instance, the observations fall below the theoretical curve in the infra-red. Abbott considers this is probably due to error and attributable to a streaky sky at the time of the observations. Procyon shows a positive departure in the infra-red, the observed values being too large. Abbott suggests that this may be effect of the companion.

By integrating his curves, Abbott deduces the ratio that stellar radiation bears to solar radiation outside the atmosphere. By assuming a parallax for the star, it is then possible to deduce the diameters of the stars referred to that of the sun as unit. On comparing the diameters deduced in this way with the diameters obtained by interferometer and other methods, it is very noticeable that for the hot stars the radiometer values are too small. Abbott suggests that the error lies in the temperatures chosen which enter into the deductions of diameter. He points out that in the case of the sun, the energy curve does not agree with the black-body curve of best fit, the observed curve being too high in the infra-red and too low in the violet. He considers that this is due to the fact that we see much deeper into the sun at longer wave-lengths, and hence see a hotter sun for long wave-rays than for shorter ones.

Abbott makes the following suggestion: "For the giant K and M stars the long wave-lengths may come from deep within the star, whilst the visible wave-lengths originate at lesser depths. Consequently, as the infra-red is relatively too high, in trying to fit the form of curve, we take a temperature which is really too low to suit the actual average temperature of emission, and the result is too large a diameter. For the hot stars, this tendency does not prevail, because their infra-red intensities are so small that they necessarily receive very small weight in the selection of the proper temperature curve. That they give diameters which are too small, if indeed this should prove to be the case when greater accuracy is attained in this and in other methods of investigating diameters, may arise partly from an error in the solar reduction constant $0{\cdot}89 \times 10^{10}$ mentioned above. On the other hand, these stars may lack much of being full radiators, so that the black-body constant may be too large for them."

It is of interest to make a brief comparison of Abbott's and Sampson's procedures. The most obvious difference is that Abbott measures the spectral intensity of light from a star of a given wave-length directly, the light falling on to the vane of the radiator, whereas Sampson photographs the spectrum and infers the energy distribution from his measures of the density distribution on the plate. Of more importance is the fact that whereas Sampson's measures cover a small portion of wave-length (roughly from $0{\cdot}39\,\mu$ to $0{\cdot}69\,\mu$), Abbott's measures extend over a much greater range ($0{\cdot}43\,\mu$ to $2{\cdot}23\,\mu$). When intensity of energy in the spectrum is plotted against reciprocal of wave-length, within the narrow limits used by Sampson the black-body curves are in most cases practically straight lines. For the longer range obtained with the radiometer this is not the case, and it is possible to compare the observed curves with black-body curves and get an idea as to how closely the radiation approximates to black-body radiation. Furthermore, the long range of wave-length covered by the radiometer method allows Abbott to integrate his curves and obtain estimates of diameters. (It must be mentioned in this connection that the comparison between the resulting values and the values deduced from interferometer measures do not really depend on the assumed parallaxes, as both methods really give apparent angular diameters, and the parallaxes are used to convert both into linear measure.) Possibly, however, the radiometer method is more cumbrous than the spectrophotometric one and is best suited for special investigations of a few stars rather than for the determination of effective temperatures in bulk.

Spectrophotometric Determinations of Stellar Luminosities.—In a recent Uppsala publication B. Lindblad determines the absolute magnitudes (that is the magnitude a star would have if it were situated at a standard distance—10 parsecs—from us) of over 1,200 stars, mostly in the Greenwich astrographic zone, by a spectrophotometric method. For the later-type stars the method consists essentially in measuring the cyanogen absorbtion in the spectral region λ 4144–4184. It is found that the amount of cyanogen absorbtion is correlated with the absolute magnitude, and consequently by measuring the cyanogen absorbtion the absolute magnitude can be inferred. The instrument used was a 15-cm. camera in conjunction with an objective prism giving a dispersion of 1·4 mm. on the plate between H_λ and H_ϵ. The cyanogen absorbtion was obtained by measuring the intensity ratio of the radiation in the regions λ 4144–4184 and λ 4227–4272, and this ratio was measured in the following way. On every plate a series of exposures was taken with exposure-times decreasing in the ratio of $\sqrt{2}$ to 1. The point in this series of images at which the density of the photographic deposit in the brighter spectral region equalled the density of deposit of the longest exposure in the fainter spectral region was estimated and the intensity ratio then calculated from the time ratio. The method was not satisfactory when applied to the early-type stars, and in their case a different procedure was adopted. For the stars of types B8 to A0 a special classification was made, the stars being classified according to the degree of sharpness of the hydrogen lines and (in the case of stars with strongly winged lines) according to colour. Lindblad finds that this scheme of classification is one according to absolute luminosity, the absolute magnitudes of the different groups being obtained from Pleiades stars, the parallax of the Pleiades being taken as 0″·0079.

In a discussion of the results, Lindblad finds a pronounced decrease in the star-density of the early-type stars beyond the distance of 200 parsecs. He gives reasons for accepting this result as real, and considers that it is confirmatory of Charlier's conclusion concerning the existence of a local star-cluster in the neighbourhood of the sun of absolutely bright stars of early type.

METEOROLOGY. By E. V. Newnham, B.Sc., Meteorological Office, London.

The Life-history of Cyclones.—The slow progress of weather prediction appears to be due very largely to the fact that the cause of cyclones is not yet fully understood. The two main difficulties in the way of a solution of this problem are the complexity of the phenomena to be studied and the expense involved in obtaining observations of the physical condition of the atmosphere at high levels. The ordinary representation of a cyclone on a synoptic chart is approximately a horizontal section of a cyclone at mean sea-level, and pictures of this kind have been accumulating in the different meteorological institutions for over half a century. It is useless to expect a solution of the problem by a study of such sections, for it is known that in the majority of cyclones the atmosphere up to at least a height of six miles is involved.

One of the earliest investigations which attacked the problem from the observational side, and was, therefore, not of a purely speculative nature, was that of W. H. Dines. He showed that in western Europe the temperature up to about a height of six miles is on the average below the normal when the surface pressure is low, and above it when the surface pressure is high; in the "stratosphere," *i.e.* from about six miles up to at least twelve miles height, this temperature rule is reversed. He found also, on working out the mutual correlation between a number of variables, such as the surface pressure, the pressure at six miles, the mean temperature up to six miles, the height at which the stratosphere begins, etc., that the pressure at six miles showed on the average the closest correlation with the remaining quantities under consideration. These interesting results have not, however, led to any simple explanation of the origin of cyclones; it is by no means certain whether they hold for cyclones in general, as those of western Europe are usually in a late stage of their life-history.

A more theoretical investigation was inaugurated by Prof. V. Bjerknes. In its early stages it was a close investigation of the weather and cloud phenomena associated with certain abrupt changes of wind and temperature at the earth's surface, and a definite theory—the Polar Front Theory—was evolved as a result of these studies. Without going into details, it may be observed that the theory implies that the normal life-cycle of a cyclone is: (1) the protrusion of warm air of "equatorial" origin into relatively cold air of "polar" origin; (2) the formation of some kind of vortex; (3) the "occlusion" of the warm air so that none is left at the surface; and (4) its gradual disappearance during the "filling-up" or death of the cyclone. Although the Norwegian theory has a considerable following at the present time, it has not been verified in detail; indeed, the systematic study of individual cyclones, with the aid of all available information about the state of the upper atmosphere, has been much neglected. In the *Quarterly Journal of the Royal Meteorological Society* for October 1924, there is a paper entitled "Further Researches into the European Upper Air Data, with Special Reference to the Life-history of Cyclones," by C. K. M. Douglas. This paper deals with certain theories about the energy of cyclones, and also includes some studies of individual cyclones arranged into two classes: firstly, those which possessed a "warm sector" of the kind postulated by Bjerknes, and secondly, those which appeared to develop entirely in polar air. A summary of these studies of individual cyclones will now be given; the desirability of collecting statistics of this kind will have been made evident from the foregoing introductory remarks about the general state of our knowledge of cyclones at the present time.

Cyclones with Warm Sectors containing Air of Equatorial Origin.—Air that had originated south of latitude 40° N. not more than three days earlier was taken to be "equatorial" in this paper. Trajectories were drawn for the "gradient-wind" level (1,500 feet above sea-level), when warm sectors were subjected to a test to see if they satisfied this definition. There is reason for believing that, in western Europe, the path of air at this level is in rough agreement with the path of air at any other height up to at least 10,000 or 15,000 feet on most days. The conclusion is drawn that if a cyclone has a warm "equatorial" sector, as defined above, then a portion of that cyclone is "equatorial" up to a great height, in some cases up to the base of the stratosphere.

In order to obtain information about the temperature at high levels in cyclones with warm sectors, examination of the temperatures recorded on the Pic-du-Midi (9,400 feet), in the Pyrenees, was made on all occasions in winter between 1895 and 1914, when the centres of such cyclones passed within 300 miles of that mountain. There were eighteen cases. It was found that when the centre was nearest to Pic-du-Midi, *i.e.* when the pressure at adjacent low-level stations was a minimum, the temperature on Pic-du-Midi was about 1° C. above the normal for the season and time of day, and showed considerable uniformity in the separate cases. In every case except one there was a pronounced fall of temperature behind the centre, which averaged 7° C. On most occasions the actual highest temperature occurred slightly in front of the centre; at the eastern boundary of the system, however, temperature averaged 5° C. lower than near the centre. A chart is given in the original memoir depicting one of these eighteen depressions—that of November 16–18, 1910—at a time when it was moving quickly east and was just over twenty-four hours old; it was in the active developing stage, and there was heavy rain over the region in front of it. The changes of temperature and pressure at Bordeaux and Pic-du-Midi are given in another figure. The temperature on Pic-du-Midi was down to about 256° A. at 18 h. on the 16th before the arrival of the centre, but rose to nearly 271° A. just before the passage of the centre on the 17th, remaining above 266° A. until midnight; it fell to 260° A. next morning, by which time the system had passed away well to the east. There was very little change of pressure on Pic-du-Midi; the depression existed, therefore, only in the lowest layers of the atmosphere. At Bordeaux the change of temperature was much smaller, and the warm phase did not last so long; pressure fell, however, to the extent of 12 millibars between the 16th and 17th and rose 14 millibars between the time of the minimum on the 17th and noon on the 18th. Another interesting case occurred outside the period systematically examined, namely on November 18, 1916. This cyclone was very deep; pressure was down to 973 millibars at 7 h. at Biarritz, and at this time the temperature was 4° C. above normal on Pic-du-Midi. There was a rapid fall of temperature on Pic-du-Midi during the next day or two as the surface pressure rose with the passing away northwards of the depression. Two further cases of cyclones with "warm sectors" are mentioned; the information about upper-air temperature was furnished in these instances by ballon-sondes. The first of these occurred on April 1, 1909, when a depression moved quickly along the north coast of Germany. The "troposphere" was warmer than the normal for April over Berlin, Strassburg, and Vienna, and was much colder than over south-east England, which was in the rear of the depression. In the second case—November 8, 1906—there was a successful ballon-sonde ascent at Brussels near the centre of a large depression. The distribution of temperature was very abnormal on this occasion, for the troposphere was rather warm for November over Brussels, very warm over Germany, but relatively cold over Switzerland, Spain, and northern Italy.

These observations show that there are cyclones that depart very widely from W. H. Dines's average cyclone; in cyclones with warm sectors his rule is reversed, judging from these twenty-one cases.

Cyclones developing entirely in Polar Air.—Polar air is here defined in a way similar to that adopted in the case of equatorial air, except that the source instead of being the region south of latitude 40° N. is the polar basin, defined roughly by the line St. Lawrence—Iceland—Stockholm—Moscow.

A typical case occurred during the period November 2–4, 1910, which was one of the periods arranged for the liberation of ballon-sondes in different parts of Europe; numerous observations of the temperature at great heights were, therefore, available. A depression which had arrived off the Norwegian coast on the 1st became very deep on that day, and in its rear great quantities of polar air spread southwards over western Europe. The troposphere was at this time very cold and the stratosphere low and warmer than is usual. During the 3rd a secondary depression advanced from off the south-west of

Ireland and was over south-east England at 18 h., reaching Germany by 7 h. next day. Just as in the case of the cyclones with warm sectors, there was a pronounced rise of temperature in the immediate neighbourhood of the centre; at Manchester there was a rise of 5° C. between 3,000 and 20,000 feet in the 24 hours ending at 17 h. on the 3rd, by which time the centre was within two or three hundred miles of Manchester, and a fall of about 4° C. during the following 24 hours at these levels; the rise at Munich and Vienna, on the near approach of the centre, was even greater. Another case is that of March 3, 1909. At noon a depression had reached the Straits of Dover, having moved down from the north and deepened. A sounding made at Pyrton Hill revealed temperatures in the troposphere well below the March normal, but at Manchester next day the temperature was much lower, the difference averaging 9° C. between 13,000 and 26,000 feet. Here again the evidence suggests that the central region of the cyclone was not cold relative to its surroundings, but the reverse.

Conclusion.—This systematic study of the temperature in the free atmosphere in individual cyclones has led the author to conclude that W. H. Dines's statistical result, that a low barometer is associated on the average with a cold troposphere, should not be interpreted as meaning that cyclones necessarily have cold cores. Over western Europe, and particularly over the British Isles, if the barometer at a given place is high, that place in most cases lies either within or just to the north of an anticyclone; the case where the anticyclone is to the north is relatively infrequent. If we can assume that the central and northern parts of anticyclones are generally warm (in the troposphere), and experience appears to support this supposition, and if, further, the troposphere has a low general average temperature during disturbed periods with frequent cyclones, then Dines's average statistical result (high barometer associated with warm troposphere, low barometer associated with cold troposphere) is explained without making any further assumptions. The evidence adduced in this paper points to the existence of a warm central core in nearly all cyclones that are not beginning to die out—a most important result, if it can be established beyond dispute. A final decision on the subject can only be reached when more detailed information about upper-air temperature is available.

PHYSICS. By J. Rice, M.A., The University, Liverpool.

In former notes (Science Progress, Nos. 71, 72) the writer has pointed out the dilemma in which Physics finds itself to-day. In all attempts to give a description of the mechanism of interaction between radiation and matter it is impossible to maintain consistency of detail if all the experimental facts are faced. If we regard the phenomena of interference, on which the action of most optical appliances depends, it is wellnigh impossible to get away from the idea of continuity bound up with the propagation of waves and the general body of classical electrodynamic theory. The electromagnetic theory of light has proved not only an admirable instrument for interpreting the propagation of radiation in free space, but it has also shown itself to be of signal power in the treatment of certain phenomena connected with the interaction of matter and radiation. Thus a general description of the emission and absorption of light, refraction, scattering and dispersion can be given on the assumption that atoms contain electrified particles which can perform harmonic oscillations about positions of stable equilibrium or states of steady motion, and which exchange energy and momentum with the radiation fields according to the classical laws of electrodynamics. Yet this interaction between matter and radiation exhibits certain features which are at variance with the classical laws, and in order to arrive at formal statements which are in agreement with experimental results one is compelled to introduce a mechanism characterised by discontinuous features which are apparently irreconcilable with the continuity of action demanded by conformity to the accepted laws. Thus, the facts of temperature radiation, of variation of specific heats with temperature, of the photoelectric effect, of ionisation by X-rays, of optical series and band-spectra, are all at variance with the deductions of classical theory, and can only be obtained by forcing discontinuous features into a mechanism which by the very nature of the concepts and definitions on which it is framed cannot receive such cavalier treatment and "survive." Thus, one extreme form of such a discontinuous process was suggested by Einstein some years ago. He put forward the view that radiation is not propagated through space as continuous trains of waves with the energy diffused in a continuous manner throughout the wave-train, but as a group of compact and isolated entities, which he christened "light quanta." Each entity holds a quantity of energy $h\nu$ concentrated in a minute volume, where h is Planck's constant and ν the number of waves which on the classical view should pass a given point in unit of time. Despite the glaring inconsistency between such a picture and the familiar mechanism of continuous propagation, it accounts for a number of vital results in photo-electricity and elsewhere which ordinary theory completely fails to explain. One obvious inconsistency is the introduction of the quantity ν, which is of course based on and defined in connection with the opposing theory. True, we can separate ν from the idea of wave-trains and relate it to the frequency of vibration of a harmonic oscillator in the atoms of the source. But, as the writer has previously pointed out to readers of this journal, it is just this mechanism of harmonic oscillators radiating continuously which Bohr originally had to scrap in order to account for the laws of optical series. In its place he substituted a picture of an atom which remains in a " stationary state " for a finite time. Such a stationary state is characterised by the fact that the electrons circulate round the nucleus in unchanging orbits and do not radiate energy at all, as they should on classical views in virtue of their acceleration. Radiation occurs only during a discontinuous change in the atom which brings it in presumably a very short period (*i.e.* short relative to its duration in a stationary state) from one such stationary state to another. Bohr does not offer any picture at all of a mechanism which would effect such transitions (*i.e.* a picture in the sense that the harmonic oscillator served as a picture of the processes of classical electrodynamics). He merely postulates such discontinuous features in the life of an atom, in order to bring the mathematical formulæ for optical series into agreement with experimental results—in his own words, his theory is a " formal " one without any attempt to sketch a mechanism whose behaviour would conform to it in the way in which the movement of a harmonic oscillator conforms to the differential equations of electrodynamics.

It is clear that any new theory, to be valid, must be prepared to embrace in its foundational principles such discontinuous elements and yet at the same time allow for the continuity which is still manifest in many physical occurrences. Now it appears that at the outset of such a new formulation of principle we must face two alternatives—shall we retain the general laws of conservation of energy and momentum, in the strict sense that they are true in relation to each individual atomic process ; or shall we abandon such a strict reading of them and be content that they should be only true in the statistical sense—that is, as an average feature of a great number of such individual processes, but not essentially true for each process considered by itself ? Thus, in the hypothesis of light-quanta Einstein is manifestly at pains to preserve the strict interpretation of these two laws. An atom, in a change from one stationary state to another, loses energy, emitting it as radiation. This energy will ultimately be absorbed by another atom as a whole, thus bringing that atom to a stationary state of greater energy content than before. The essence of the light-quantum hypothesis is the view that the energy will be absorbed entirely and " at one swoop " ; there it differs from the classical view, which pictures it being absorbed gradually and by many atoms. Yet this view and the classical one have so much in common that they regard the conservation of energy strictly obeyed all through. In so far as the energy is not in an atom, it is in the radiation. Yet such a notion of the propagation of light as the flight of "corpuscles" of energy introduces difficulties apparently so insuperable when applied to the explanation of interference that it seems to exclude in principle the possibility of defining in a rational way such a concept as frequency. In the words of Bohr, "the satisfactory manner in which the [light-quantum] hypothesis reproduces certain aspects of the phenomena is rather suited for supporting the view, which has been advocated from various sides, that, in contrast to the description of natural phenomena in classical physics in which it is always a question only of statistical results of a great number of individual processes, a description of atomic processes in terms of space and time cannot be carried through in a manner free from contradiction by the conceptions borrowed from classical electrodynamics, which, up to this time, have been our only means of formulating the principles which form the basis of the actual applications of the Quantum Theory."[1]

As may be inferred from this quotation, Bohr and his co-workers prefer to attack the problem in another manner, which allows for the retention of the conception of the spreading wave of the classical theory as regards propagation in free space, while importing the new idea of discontinuous transitions into the purely atomic processes. In order to achieve this object, however, the strict interpretation of the laws of conservation has to be abandoned, and the equalities of losses and gains regarded as a statistically true result, but not an individually exact one. An important paper outlining this position appeared about a year ago in the *Phil. Mag.* (vol. 47, No. 281, May 1924), a joint production by N. Bohr, H. A. Kramers (who has been associated with the great Danish physicist for some years), and J. C. Slater of Harvard; and two other papers on similar lines have appeared recently in the *Physical Review*, one by J. H. Van Vleck (October 1924) and one by J. C. Slater (April 1925). It should also be mentioned that Louis de Broglie, who has tried to soften the contradictions of the light-quantum hypothesis and to whose work a reference was made in a previous communication to this journal (SCIENCE PROGRESS, No. 72, April 1924, p. 525), has recently published a very long paper on these matters in the *Annals de Physique* (January, February, 1925).

The two postulates of the Bohr Theory are the assumption of stationary states and the law of emission, which claims that when the atom passes discontinuously from one stationary state to another of lower energy content it emits energy in the form of a *monochromatic* radiation whose frequency is given by dividing the energy loss by the Planck constant, *h*. (For a fuller statement of these postulates and of the " Principle of Correspondence," to which reference will be made presently, consult the note in SCIENCE PROGRESS, No. 71, January 1924). Inversely, it is assumed that the reversed process of transition from the state of low energy content to that of higher can take place if the atom be illuminated by light of this same frequency. At present, the formal treatment of this idea is based on considerations of probability (already used with great success by Einstein in deducing Planck's law of full radiation). The transition to another state of *lower* energy content is regarded as in part " spontaneous," *i.e.* having *apparently* no connection with external influences ; the probability of such a change (*i.e.* the fraction of a great number of atoms which are now in the first stationary state and which within the lapse of unit time will " jump " to the second state in this " spontaneous " way) is regarded purely as a function of those two states. In addition to this spontaneous probability of changing to a lower energy state there is also a probability of this change, which depends on the specific density of the radiation, whose frequency corresponds to this transition, around the atom. The probability of this " induced " transition is in fact measured by the product of the specific energy-density of the surrounding radiation (of the suitable frequency) and a " coefficient " also determined by the states in question. Thus the total probability of the change to a lower energy content is the sum of two parts, one depending on the radiation from elsewhere illuminating the atoms, and the other not so dependent but having a " spontaneous " character somewhat analogous to a corresponding conception in radio-active processes. It is taken for granted that the reverse transition from the state of lower energy content to the one of higher content has no " spontaneous " character about it, but must be brought about by illumination of the atom with light of the right frequency, the probability of this " induced " transition being, as before, the product of the specific energy-density of the illuminating radiation and a coefficient. (It should be noted that the coefficient for an " induced " transition one way is not necessarily equal to the coefficient for the " induced " reverse transition.) As stated above, the support for these definite postulates, as regards probability of transition, consists in the very simple deduction of Planck's heat-radiation formula which they afford, a fact first pointed out by Einstein. As is well known, the results deduced from the Bohr postulates agree very well with the results deduced from classical theory when we consider processes which depend on the statistical behaviour of a large number of atoms and which involve transitions between stationary states which are so near to one another that there is comparatively little difference between them—*i.e.* states for which the quantum numbers are large and the differences of the quantum number small in comparison. Bohr never fails to insist that, even in this limiting region of approximate agreement in formal deductions, there is nevertheless no question of a gradual diminution of the difference between the description by the Quantum Theory of the phenomena of radiation and the ideas of classical electrodynamics, but only of an asymptotic agreement of statistical results. It is this measure of agreement which is the root of the "Correspondence Principle" (see SCIENCE PROGRESS, No. 71) which supplements the postulate concerning energy-difference of states and frequency with a further hypothesis concerning intensity and polarisation. For the purposes of stating this principle we have, on the one hand, to consider the various harmonic components which enter into the Fourier series which represents the periodic motion of an electron in a stationary state; on the other hand, we have to consider all the possible transitions from this state to other stationary states. It appears that a very direct method can be found of setting up a one-one correspondence between each possible transition and one term of the Fourier series, *i.e.* one harmonic oscillation component in the totality of such components into which the electrical moment of the atom, considered as a function of the time, can be resolved. Briefly we "conjugate" each possible transition with a simple harmonic term of the analysed electrical moment. The essence of the correspondence principle is briefly stated as follows. Of all the atoms considered, a certain number are in a given stationary state at the moment (this number being determined by statistical methods). Within the lapse of a given time a certain fraction of these will jump to another stationary state, another fraction will jump to still another, and so on; there will be for some fraction of the group in the given stationary state a jump to one of the other stationary states, the fraction depending on the probability considerations outlined above. Each such sub-group effecting such a jump will react on the radiation field in a particular way, through emission or absorption. The reaction of such a sub-group on the field is compared with the reaction which, *on the classical theory*, we would expect from this sub-group were each member of it the seat of an electrical harmonic oscillation given by the term of the Fourier series "conjugated" with the particular jump effected by the atoms in the sub-group. Thus the

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[1] *On the Application of the Quantum Theory to Atomic Structure.* N. Bohr, published by the Cambridge University Press.

" quantum " reaction of the whole group *in the given stationary state* is compared with the " classical " reaction of a set of oscillators whose frequencies and vector amplitudes are determined by a set of terms in the Fourier expansion each one of which is conjugated with a jump from the given stationary state to every other stationary state. This comparison has proved successful in certain cases in settling questions of intensity and polarisation of the actual radiation—matters which are not considered at all in the first two postulates of the Bohr Theory, and the new idea from Bohr and his co-workers concerns a suggested new rôle for these " virtual " harmonic oscillators.

In the classical theory one atom is continually acting on another, not in the instantaneous way pictured in the early " action at a distance " theories, but through the medium of the field of radiation into which each atom is pouring energy continuously and from which each atom is continuously drawing energy, this being the most obvious concomitant of such action. As far as the postulates of the Quantum Theory enunciated above are concerned it would appear, in direct opposition to this, that so long as an atom is in a stationary state it cannot act on another atom.[1] Not until it executes a transition and so releases some energy which, after travelling through the medium, induces a contrary transition in another atom can interaction with other atoms be considered as possible. So for comparatively long periods each atom does not act on any other. Now it is here that the paradox between the spreading field and the concentrated " light-quantum " field arises. Closer consideration shows that the difficulty is bound up with the implicit assumption, so natural and so deep-rooted in our minds through our habitual attitude to matters of General Physics, that no change can take place in any isolated piece of matter, however small, until the energy accompanying the change has been exactly supplied, neither more nor less. That is why we are at a loss to understand the photoelectric effect on classical lines ; no doubt all the energy required for ejection of the electron from an atom is there ; it has been emitted, and is in the radiation field ; but, with the spreading wave, how has it got into this particular atom ; why is it not in other atoms which the widely diffused wave has travelled past ? And yet concentration in light-quanta, while giving us a picture of how it might be done, completely destroys another picture equally necessary for other phenomena. The writers referred to do not offer to untie this Gordian knot—they want to cut it.

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[1] It is assumed here that the atoms are not so close that the forces arising from the radiation are small compared with the conservative forces arising from the electric charges in the atom. In short, nothing in the way of a encounter or collision is happening.

They maintain that we must conceive of an atom, *even when in a stationary state*, continuously acting on distant atoms so that presently a transition will be induced in any distant atom without of necessity the " acting " atom executing beforehand a reverse transition to supply the energy which we are accustomed to say is " necessary " for the induced transition. If this claim be maintained it is clear that we shall have to abandon the use of the word " necessary " in connection with individual atomic changes ; but that does not mean that we must abandon it entirely. It may still be used justifiably in reference to a great number of such processes. Provided over a lapse of time the energy required for the sum-total of all the processes in a finite portion of matter is forthcoming, that appears to be all that is required. The energy may spread ; through each atom will travel a portion of the energy, even in a spreading wave ; but the change in the atom may take place either before or after the moment at which the energy involved in the change to a new stationary state has arrived. The atom may, as it were, be a " debtor " or a " creditor " to the radiation field ; but there will be no real breach of the *experimental* principle of conservation ; for it will always " balance " its accounts " over sufficiently long periods. In short, conservation will become a statistical principle *as far as atomic processes are concerned.*

Of course, the mind demands some picture of a space-time mechanism by means of which this continuous action of an atom in a stationary state on a distant atom can be effected. The authors referred to assume that, whatever it is, it is " virtually equivalent with the field of radiation which on the classical theory would originate from the virtual harmonic oscillators corresponding with the various possible transitions to other stationary states." During the comparatively long period in which an atom is in a stationary state it emits no energy, and yet it is acting on a distant atom in a way which is equivalent to the manner it would act on it were each atom to contain the virtual harmonic oscillators conjugated with the immediate stationary state and classical interaction going on. Further, it is assumed that the transition processes of the Quantum Theory are connected with this mechanism (which is so equivalent to the virtual harmonic oscillators) by probability laws analogous to those outlined above. In classical theory there is a reaction on a radiating oscillator by the radiation field itself ; so, on the new view put forward, those transitions in an atom which have been designated as " spontaneous " by Einstein are regarded as induced by the virtual field of radiation which is connected with the virtual harmonic oscillators conjugated with the motion of the atom itself in the stationary state, which it leaves on such a " spontaneous " transition taking place. On the other hand, the induced transitions of Einstein's theory occur in consequence of the virtual radiation in the surrounding space due to other atoms. These assumptions in a way increase the significance of the virtual mechanism which is set up in order to apply the correspondence principle; they do not involve any change in the use of that principle to discover the intensity and state of polarisation of light emitted from an atom of given structure, nor do they interfere with the application of the first two postulates to the determination of the frequency of the light. But they do lead to a picture of the occurrences of the various transition processes on which the observations of optical phenomena ultimately depend, which differs from the usual ideas about these processes in an essential respect. Thus, we have been accustomed to connect the occurrence of a certain transition in a given atom with the occurrence of transition processes in other atoms, the connection being closely bound up with the conservation of energy and momentum in a very strict sense. If the new suggestion finds support we will not link the transition process in the given atom with transition processes in the other atoms, but with the actual *stationary state* of the given atom and with the *stationary states* of the atoms with which it is at the moment in communication through the virtual radiation field. In fact, as regards the occurrence of transitions, which is the essential feature of the Quantum Theory, one abandons any attempt at a causal connection between the transitions in distant atoms and especially a direct application of the principles of conservation of energy and momentum. Thus, it is assumed that an induced transition in an atom is not directly caused by a transition in a distant atom for which the energy difference between the initial and the final stationary state is the same. On the contrary, it is considered as possible that a given atom in a given stationary state may contribute to the induction of a transition in a distant atom through the virtual radiation field connected with the virtual harmonic oscillator which is conjugated with the given stationary state in the given atom and a second stationary state, and yet that the given atom may ultimately not jump to that second stationary state, but may perform quite another transition.

Thus, the cause of the observed *statistical* conservation of energy and momentum is not sought for in a departure from electrodynamic theory as regards the laws of propagation of radiation in free space, but in the peculiarities of the mechanism of continuous interaction between atoms, which, although it is not pictured, is yet regarded as equivalent in its effects on any atom to the interaction between the virtual field of radiation and the atom. The illuminated atoms are regarded as secondary sources of virtual wave radiation which interferes with the incident radiation. If we have close agreement in frequency between the incident wave and one of the virtual harmonic oscillators corresponding to possible transitions, the amplitudes of these secondary virtual waves will be large, and so the intensity of the virtual radiation field may be augmented or diminished so far that the induction of transitions in the atoms may be increased or diminished considerably. An augmentation of the virtual field will take place if the secondary wavelet is connected with a virtual harmonic oscillator conjugated to a transition in which the atom passes to a stationary state of lower energy, and *vice versa*. On this view the occurrence of a transition in an atom simply terminates an interval during which the atom has been acting on distant atoms in a way equivalent to the classical action of a certain group of harmonic oscillators, and initiates an interval during which it will act on distant atoms in another way equivalent to the action of another group of oscillators.

The authors anticipate that, although the quantum mechanism of continuous interaction may not as yet be pictured, yet the analogy which they have drawn between it and the virtual harmonic oscillators and virtual radiation field may lead to the establishment of a fairly complete and consistent description of the general optical phenomena accompanying the propagation of light through a material medium, which will at the same time account for the close connection of these phenomena with the spectra of the atoms of the medium. Thus they have been able to set up, on their view, a quantitative theory of dispersion a brief account of which is given in *Nature* (May 10, 1924) and a fuller account in the papers to the *Physical Review* referred to above. A striking result is the deduction of a dispersional formula of the familiar type, in which, however, there are terms with an essentially negative coefficient, a deduction which should be within the power of experiment to verify or refute.

Readers of this journal will recognise that these authors are seeking to remove the paradoxes of the Quantum Theory in a manner which differs markedly from the attempts of L. de Broglie, to whose work a reference was made above. A distant analogy might be drawn between de Broglie's "phase-wave" and the virtual radiation field of the preceding pages, but the underlying ideas and method of development are quite different. It remains for experiment to discriminate if possible.

RECENT ADVANCES IN BIOCHEMISTRY. By R. Keith Cannan, M.Sc., University College, London.

That the discovery of insulin should have stimulated an interest in the biochemistry of glands other than the pancreas can scarcely be a matter of surprise. It is, however, particularly gratifying that the first success in these extended researches should be claimed by one who did so much towards the isolation of the pancreatic hormone. J. B. Collip, who, it will be remembered, devised the first method for the preparation of insulin, now reports that he has obtained from the parathyroid gland extracts possessing properties which must be attributed to a hormone of that gland.

It has long been known that removal of the parathyroid gland from an animal results in a definite clinical syndrome—tetania *parathyreopriva*—followed inevitably by death. The condition may be accentuated by a meat diet or by the administration of alkalis, whilst it may be relieved, as has been shown by A. B. Luckhardt and B. J. Goldberg (*J. Amer. Med. Assoc.*, 1923, **80**, 79), by massive doses of calcium lactate, or by the intravenous injection of small amounts of calcium salts (H. A. Salvesen, *J. Biol. Chem.*, 1923, **56**, 443). It has further been established that parathyroid tetany is accompanied by a reduction in the concentration of calcium in the blood. I. Greenwald (*J. Biol. Chem.*, 1924, **59**, 337, and **61**, 33) has discussed at length the various theories of the cause of tetany in parathyroidectomised dogs, and has arrived at the conclusion that there are only two authenticated metabolic changes following removal of the gland. One is a fall in the calcium concentration of the blood and the other a reduced excretion of phosphorus. He finds no evidence for the occurrence of a definite intoxication. This latter criticism is directed towards the hypothesis of D. N. Paton and L. Findlay (*Quart. J. Exper. Physiol.*, 1916, **10**, 203, 315, and 377, and later papers with D. Burns and J. S. Sharpe in the same journal) that the condition is one of guanidine intoxication. The experimental work of Collip, now to be discussed, would have appeared to have established beyond question a primary relation of the blood calcium level to the condition of parathyroid tetany. He first observed that the administration of an acid hydrolysate of the gland to a parathyroidectomised dog removed the tetanic condition coincident with the re-establishment of a normal concentration of calcium in the blood (*J. Biol. Chem.*, 1925, **63**, 395). Attention was then directed to the preparation of more active material. Briefly, the method now reported consists in the hydrolysis of the gland with 5 per cent. hydrochloric acid at 100° C. for one hour. The fat is then removed and the protein precipitated by a suitable adjustment of the reaction.

Two c.c. of the filtrate corresponded to one ox gland, and was found to be a potent preparation as judged by its effect in allaying tetany and in raising the level of serum calcium. Collip promises an early report of further purification of this extract and appears to be optimistic concerning the relative simplicity of the active principle. The extract is effective when administered intravenously, subcutaneously, or by the oral route.

The extensive data presented leave little doubt that we have now available a preparation of the hormone of the parathyroid gland which will completely allay tetany in animals from which the gland has been removed, even when a heavy meat diet is given. Moreover, this curative effect is closely associated with the re-establishment of a normal blood calcium concentration. Indeed, overdosage will result in an increase of this concentration above the normal. In such case, or when the hormone is administered to the normal animal (*J. Biol. Chem.*, 1925, **63**, 439), the resulting hypercalcæmia is accompanied by very definite symptoms. There is observed loss of appetite, drowsiness merging on coma, failing circulation, and an obvious condition of dehydration of the animal. If the treatment is persisted in, the result is the death of the animal. The analogy between the relation of the pancreas to the blood-sugar level and the relation of the parathyroid to the blood-calcium level is so obvious as to require no emphasis. The normal concentration of calcium is 11–13 mgms. per cent. In the parathyroidectomised animal this falls to about 6 mgms. per cent. with the onset of tetany. On the other hand, when the hormone is administered to the normal animal, the calcium concentration rises, in about six hours, to 16 mgms. per cent. or more, and then slowly returns to normal over a further period of eighteen hours. Whereas hypercalcæmic symptoms supervene when the blood calcium reaches about 16 mgms. per cent., it is possible, by excessive or persistent dosage to push up the amount of calcium to as much as 20 mgms. per cent. The phosphorus concentration of the blood also rises, but at a much slower rate than the calcium.

The two communications of Collip and his associates which have so far appeared may be considered as preliminary. Nevertheless, the amount of experimental work recorded is extensive, and it seems certain that these workers were actually handling a hormone of the parathyroid gland, whose special function is the nice control of the concentration of calcium in the blood. The immediate prospect is alluring. We shall await impatiently progress in the chemical purification of their extracts.

There has been placed in the hands of the physiologist a new means for the study, not only of the function of the parathyroid gland, but also the wider and elusive problem of inorganic " metabolism."

The Anti-Rachitic Properties of Light.—The relation of light to the fat-soluble vitamins is becoming rapidly clarified. We have good evidence that the growth-promoting vitamin is a product of photosynthesis in the green leaf, whereas green foods may be relatively poor sources of the anti-rachitic factor (R. M. Bethke, D. C. Kennerd, and M. C. Kik, *J. Biol. Chem.*, 1925, **63**, 337 and earlier literature cited there). Nevertheless it will appear that the anti-rachitic vitamin is equally a photochemical product, though the laboratory in which Nature synthesises it is not specifically the green chloroplast.

A year ago there was reported in these reviews the suggestion of E. M. Hume and H. H. Smith (*Biochem. J.*, 1923, **17**, 364) that they had succeeded in conferring upon air anti-rachitic properties by irradiation with ultra-violet light. So challenging an observation could scarcely escape criticism and T. A. Webster and L. Hill reported complete failure to confirm the experiments (*Biochem. J.*, 1924, **18**, 340). J. S. Hughes, C. Nitcher, and R. W. Titus (*J. Biol. Chem.*, 1925, **63**, 206) have likewise failed to find irradiation at all effective in preventing leg weakness (rickets) in chicks, although the direct irradiation of the chicks was effective. E. M. Nelson and H. Steenbock (*J. Biol. Chem.*, 1924, **62**, 575) appear to have found the explanation for these conflicting results when they suggested that in the experiments of Hume and Smith the positive results were due to a photochemical effect upon the sawdust, food, or excreta which might have been in the " empty " cages when they were irradiated. This explanation has been accepted by the latter authors in a very recent paper (*Biochem. J.*, 1924, **18**, 1334). From the laboratories of H. Steenbock and of A. F. Hess there have appeared series of papers which have independently shown that anti-rachitic properties may be conferred upon foods, vegetable fats, etiolated leaves, and green leaves by exposure to the mercury vapour quartz lamp for a suitable period (Steenbock and Nelson, *J. Biol. Chem.*, 1924, **62**, 209, and Steenbock and Black, *ibid.*, **61**, 405; A. F. Hess and M. Weinstock, *Proc. Soc. Exp. Biol. and Med.*, 1924, **22**, 5; and *J. Biol. Chem.*, 1924, **62**, 301). Their latest papers report success in activating purified cholesterol and phytosterol by means of ultra-violet light (*J. Biol. Chem.*, 1925, **62**, 209, and **63**, 297), an observation made independently by J. C. Drummond and K. Coward (private communication).

It would seem that there has been found in cholesterol or analogous compounds the raw material from which the anti-rachitic vitamin is produced under the action of suitable radiant energy. Such a view is adequate to explain the diverse results which have been recorded in experiments involving the irradiation of animals, plants, foods, excreta, etc. The distinction between the photosynthesis of the growth vitamin and the anti-rachitic factor is plain and from the practical point of view would emphasise the necessity to good stock breeding of both green foods and sunlight.

Foods and oils when activated by light retain their potency for several months, whereas the activated cholesterol is much less stable and deteriorates in a few days. The activation is not conditioned by the presence of oxygen, but is sensitive to the amount of irradiation. Thus two hours' exposure to the mercury vapour lamp may give potent preparations of cholesterol, whereas an exposure of eight hours will result in an inactive product. The opportunity seems to be now offered for extensive work on the chemical nature of the anti-rachitic factor, if means can be found for stabilising the activated cholesterol. Meanwhile, physiologists will not fail to record that an important physiological function may at last be attributed to a substance whose " physiological inertness " has long been a mystery.

Hæmoglobin.—The respective states of oxidation of hæmoglobin and methæmoglobin have long been the subject of investigation and debate. If hæmoglobin be represented by Hb, it is customary to give to oxyhæmoglobin the formula HbO_2. It is generally agreed that methæmoglobin contains less oxygen than the oxygenated compound, but the decision between the formulæ HbO and HbOH has remained open. W. Kuster (*Z. Physiol. Chem.*, 1910, **66**, 244) was the first to indicate that, whereas oxyhæmoglobin and hæmoglobin are ferrous compounds, in methæmoglobin the iron exists in the ferric state. He gave to the latter the formula HbOH. The full significance of this distinction has not been generally appreciated, emphasis having been placed not upon the state of oxygenation of the iron atom, but upon the amount of oxygen combined in the methæmoglobin molecule. Thus, in two recent papers (Roaf and Smart, *Biochem. J.*, 1923, **17**, 579, and Quagliariello, *Arch. sci. biol.*, 1923, **5**, 193) it has been shown that half as much oxygen is combined in methæmoglobin as that found in the oxyhæmoglobin, and it is concluded that the former is, therefore, to be represented by the formula HbO. J. B. Conant has approached the problem by a new method (*J. Biol. Chem.*, 1923, **57**, 401). He has found that the system methæmoglobin-hæmoglobin is electromotively active and reversible. The reductant may be titrated with potassium ferricyanide or the oxidant with sodium hydrosulphide, and the oxidation-reduction potentials derived from these titrations are found to be in agreement with those derived from the electrochemical equation. Moreover, these results demonstrate beyond question that in the change from either substance to the other there is involved one hydrogen equivalent. Strictly speaking, therefore, we have not to consider how much oxygen is combined in the oxidant any more than we consider the amount of oxygen combined in the product of the oxidation of ferrous chloride. We are dealing with complex ions differing by one valency, or we may say that we are dealing with a change involving the loss or gain of one electron by the hæmoglobin compound. Kuster's formula is correct if we understand it to mean $Hb^+ OH^-$.

Conant points out the close analogy between the blood pigment and certain aminoferrocyanides and suggests similar co-ordinated formulæ for oxyhæmoglobin, hæmoglobin, and methæmoglobin in which the two former are written as ferro-compounds and the latter as a ferri-compound. These formulæ must be suitably modified for the reaction of the solution since the pigments are amphoteric and may exist as ions, undissociated molecule, and, probably, internal salts, but the general relations may be depicted as follows:

	Acid.	*Isoelectric.*	*Alkaline.*
Hæmoglobin . .	H_3HbH^+	$H_3(Hb)$	$Na_3(Hb)$
Oxyhæmoglobin .	$H_3(HbO_2)H^+$	$H_3(HbO_2)$	$Na_3(HbO_2)$
Methæmoglobin .	$H_2(Hb)H^+$	$H_2(Hb)$	$Na_2(Hb)$

There still remains the necessity to reconcile the fact observed by Quagliariello and by Roaf and Smart that when hæmoglobin reacts with oxygen to form methæmoglobin, one atom of oxygen (two hydrogen equivalents) is involved, whereas, when the oxidation or reduction is effected by other reagents (Conant), only one hydrogen equivalent is concerned. Conant is content to point to the many occasions in which oxidations brought about by molecular oxygen—the auto-oxidations of quinones, etc.—pursue a similar anomalous course. In any case we may say that only half the oxygen which disappears is concerned with the oxidation to methæmoglobin. In a second paper (Conant and Fieser, *J. Biol. Chem.*, 1925, **62**, 595) the question of the relation of the oxygen tension to the reversibility and equilibrium of the system hæmoglobin-methæmoglobin is considered, and the results are of very wide interest. The discussion of these will be reserved until their obvious applications have been worked out, though we may note that one interesting extension of the work has already been reported (J. M. Neill and A. B. Hastings, *J. Biol. Chem.*, 1925, **63**, 479). We must be content to record that this paper deals with an extension of Conant's work to the question of the relation of molecular oxygen to biological oxidation.

Still one further aspect of these results deserves comment.

Conant shows that the reaction of hæmoglobin with ferricyanide proceeds to an equilibrium dependent upon the oxygen pressure above the solution and upon the hydrogen ion concentration. In alkaline solution under low oxygen pressure the reaction proceeds to completion, whereas, in a neutral solution saturated with oxygen, equilibrium is attained when only 80 per cent. of the theoretical amount of methæmoglobin is formed. These results agree with the electro-chemical formulation and Hill's equation and form an independent test of these. They also define the conditions under which Haldane's method for the determination of the oxygen capacity of the blood can be exact.

In a third paper from the same laboratory (*J. Biol. Chem.*, 1925, **62**, 623) a method is developed from the electrochemical findings for the determination of methæmoglobin in the presence of its cleavage products.

PHYSICAL CHEMISTRY. By W. E. Garner, M.Sc., University College, London.

Mechanism of Chemical Reaction.—In view of the large amount of experimental work already published on the velocity of chemical reactions, it is remarkable that so little has been discovered as to the actual mechanism even of the simplest chemical reaction. It is still possible to maintain the most diverse and contradictory theories of chemical reactivity, ranging from a purely radiation hypothesis to one which demands a collision between three molecules or two molecules and a quantum of energy (Born and Franck, *Z. Physik.*, 1925, **31**, 411). An experimental test of these speculations presents great difficulties.

Bodenstein, Lütkemeyer, and Müller (*Z. Elektrochem.*, 1924, **30**, 416; *Z. physikal. Chem.*, 1924, **114**, 234), from a study of the reactions of bromine with hydrogen, have been able to throw light on the mechanism of the combination of atoms to give di-atomic molecules. The work is in partial confirmation of the theories of Polanyi (*Z. Physik*, 1920, **1**, 337), Herzfeld (*Z. Physik*, 1922, **8**, 132), and Christiansen (*Z. physikal. Chem.*, 1923, **103**, 91; *ibid.*, 1923, **104**, 451), according to which a collision between two atoms gives rise to a stable molecule only if the energy of reaction of the complex formed is removed by collision with another molecule. This theory is of great value in explaining homogeneous catalysis.

Bodenstein and his co-workers have found that the velocity of the reaction between hydrogen and bromine to give hydrobromic acid is given by the equation

$$d[2HBr]/dt = k[H_2] \cdot \sqrt{[Br_2]}/(m + [2HBr]/[Br_2]),$$

the reaction occurring in the following steps:

1. $Br_2 = 2Br$.
2. $Br + H_2 = HBr + H$.
3. $H + Br_2 = HBr + Br$.
4. $H + HBr = H_2 + Br$,

the hydrogen atoms produced in reaction (2) undergoing combination according to reactions (3) or (4). Now in the presence of iodine the velocity of the above reaction is reduced, very probably owing to the reaction (5) $H + I_2 = HI + I$. The removal of the hydrogen atoms by iodine decreases the formation of bromine by equation (3), and the iodine atoms formed are incapable of reacting with hydrogen molecules to give hydriodic acid since this change is strongly endothermic. In the presence of an excess of iodine it is possible to limit the formation of bromine atoms to equation (1), and from the rate of formation of hydrobromic acid (2) to deduce the velocity of dissociation of bromine molecules into atoms. Since the equilibrium constant for reaction (1) can be determined experimentally, the velocity of the back reaction, the rate of combination of the bromine atoms to give bromine molecules, can readily be obtained. This is found to be 1/120 of that calculated from the total number of collisions between the bromine atoms present.

This result is only approximate owing to uncertainties in the method of treatment, but it has been confirmed by more accurate measurements on the photochemical reaction between hydrogen and bromine. The velocity is given by

$$d[HBr]/dt = k\sqrt{J_{abs}} \cdot [H_2]/(1 + ([HBr]/10[Br_2])),$$

an equation which is deducible directly from the equation for the thermal reaction above. The measurement of J_{abs}, the light absorbed, makes possible a calculation of the rate of dissociation of bromine molecules under the action of light, assuming that one quantum is absorbed per bromine molecule. A comparison between the velocity of the photochemical and thermal reactions yields, in conjunction with the known dissociation equilibrium constant for bromine molecules, the velocity of combination and the concentration of the bromine atoms. From the concentration of the atoms, the number of collisions can be calculated and it is found that the percentage of fruitful collisions is 1·25.

According to the theory of Herzfeld, the percentage of the complexes formed from bromine atoms which undergo collision with another gas molecule before dissociation occurs is about 1·0 at atmospheric pressure. This is in agreement with experiment, but the percentage should depend on the total pressure and the temperature, whereas Bodenstein finds that it is independent of the pressure and temperature over the ranges he has investigated.

This discrepancy if confirmed will necessitate a revision of the above theories of chemical reactivity. It would appear that the factors which decide whether the complex between the bromine atoms will undergo reaction (*a*) Br – Br → 2 Br or (*b*) Br – Br → Br_2 + Q are independent of the gas pressure, so that the removal of Q by collision is not an essential part of the mechanism of the reaction. The ratio of the probabilities of the two processes would appear to be dependent on the internal character of the complex, such as its energy content and the degree of penetration of the bromine atoms on collision.

Anisotropic Liquids.—Important changes have been introduced into the methods of classification of liquid crystals during the last few years, but these have not met with general acceptance. Lehmann, in his original classification, sharply distinguishes between " flowing " crystals and liquid crystals. The former, including those viscous crystals which very readily undergo deformation on the application of unilateral pressure, are grouped with solid bodies, and the latter, which possess no definite external crystalline form, are placed in a class by themselves. As an alternative to this method of classification G. Friedel divided anisotropic liquids into two sub-groups, *liquide à fils* and *liquide à conique*, a division based on their appearance under polarised light. These he replaced later (*Ann. de Physique*, 1922, ix, **17–18**, 304) by sub-groups termed nematic, cholesteryl, and smectic respectively. According to this author, the nematic and cholesteryl types are characterised by an arrangement of the molecules in chains orientated normally to the surfaces of the liquid. In the cholesteryl but not in the nematic type the chains of molecules are arranged spirally and rotate the plane of polarised light. The smectic type show a focal structure, *liquide à conique*, and are characterised by the orientation of the molecules in one set of equidistant planes.

Evidence as to the structure of anisotropic liquids was sought by subjecting them to *X*-ray examination. E. Hückel (*Physikal. Z.*, 1921, **22**, 561) showed that bodies of the nematic and cholesteryl types gave no evidence of structure on examination with *X*-rays, but de Broglie and E. Friedel (*C.r.*, 1923, **176**, 738) found that the oleates of ammonium, sodium, and potassium gave reflections with *X*-rays corresponding with planes of molecules at a distance apart of 43·5 A.U. and also obtained faint reflections corresponding with smaller distances. These soaps are included by Friedel in the smectic class, and this procedure was followed by Piper and Grindley (*Proc. Phys. Soc.*, 1922, **35**,

269) in their conclusions based on an *X*-ray examination of soap curds. According to Friedel's definition, the molecules, in the smectic state of matter, are orientated in planes in which, however, they are free to move. Thus the symmetry is in one direction only. It is thus doubtful if the inclusion of soap curds as examples of the smectic class is justified on Friedel's own definition of this sub-group, for these substances show evidence of orientation of the molecules in three different directions in space. McBain (*Nature*, 1924, **113**, 534; **114**, 49) definitely comes to the conclusion that soap curds are solid crystals, thus adopting the original Lehmann classification. He has also shown that certain soap solutions, typical *liquide à conique*, do not give evidence of structure under *X*-rays. On the other hand, E. Friedel (*Cr.*, 1925, **180**, 269) finds that ethyl *p* azoxy benzoate and ethyl *p* azoxy cinnamate, also *liquide à conique*, definitely possess a smectic structure, the distance between the planes being greater for the anisotropic liquids than for the solid state. No trace of any other directions of orientation was found.

The position of soap curds is unsatisfactory; they show a molecular orientation which is almost as complete as for the crystalline condition, and certainly greater than that in the smectic state. They appear to occupy an intermediate position in the existing classification.

The lack of agreement between the results of the optical and *X*-ray examination of anisotropic liquids would seem to show that a rigid classification of liquid crystals is impossible. The various types merge one into the other. The varying degree of mobility of the molecules in different anisotropic liquids produces differences in the amount of the orientation, which in certain cases, although capable of giving rise to double refraction, is so slight as not to be detectable by *X*-rays.

It must not be forgotten, however, that certain substances give rise to two distinct anisotropic liquid forms which are non-miscible, each possessing its own range of stability.

Streaming Anisotropy of Colloidal Solutions.—Colloidal solutions containing particles non-spherical in shape when placed in an electric or magnetic field may show birefringence and dichroism owing to the orientation of the particles. This anisotropy is also shown when the colloidal solutions are streamed through a tube or are rotated. Ferric oxide, vanadium pentoxide, benzopurpurine and other dyestuffs, soaps, gelatine, etc., when present as colloidal particles in solution show these phenomena. There is a tendency for rod-like particles in colloidal solution to be arranged in swarms in which all the rod-like particles are parallel (A. Szegvari, *Z. physikal. Chem.*, 1924, **112**, 295).

Vanadium pentoxide sol is especially suitable for investigation since it gives rod-like particles of one type. Freundlich (*Z. physikal. Chem.*, 1924, **114**, 161) has made quantitative measurements on the double refraction and dichroism of streaming and rotating vanadium pentoxide sols. The anisotropy is zero with a freshly prepared sol, but increases to a maximum with age with a speed following the equation for a reaction of the second order. The temperature coefficient of the ageing process is about 4 per 10°. The anisotropy depends on the streaming velocity, the particles arranging themselves the more nearly parallel to the direction of flow the higher the velocity and the larger the particle. Lyophobic colloids in which the particles, themselves isotropic, are of elongated shape show a positive birefringency, whilst with tabular particles the birefringency is negative (A. Frey, *Koll. Chem. Beihefte*, 1925, **20**, 209).

The specific inductive capacity of a sol of vanadium oxide increases with age in the same manner as the anisotropy (J. Errera, *Bull. Soc. chim. Belg.*, 1924, **23**, 422, 432). The time required for the particles to respond to the field is 10^{-7} seconds, and at high frequencies there is little time for the field to exert its directive action. Thus the specific inductive capacity depends on the frequency of the alternating currents used in the measurements.

These properties decrease with rise in temperature due to increased Brownian movement of the particles.

Electric Moments of Pure Substances.—The unsymmetrical distribution of positive and negative electricity in chemical molecules gives rise to dielectrical phenomena which play a large part when chemical substances are employed as solvents. The researches of P. Walden on the relationship between dielectric constant and ionising power are well known in this connection. He and O. Werner have recently added to our knowledge on this aspect of the subject by a study of the dielectric constants of the chloro paraffins and olefines (*Z. physikal. Chem.*, 1924, **111**, 465). They find that the solubility of mercuric chloride in these solvents is proportional to their dielectric constants, and that the greater the dielectric constant the higher the ionising power. Their results possess an interest from the point of view of the structure of the chloroderivatives, particularly those for the stereoisomeric di-chlorethylenes, $C_2H_2Cl_2$. For the cis-form, $\epsilon = 3{\cdot}67$, and for the trans-form, $\epsilon = 7{\cdot}55$ in the liquid condition. This shows the highly constitutive character of the dielectric constant. Since the "specific polarisation" $\mathfrak{P} = (\epsilon - 1)/(\epsilon - 2)$, the molecular polarisation of the trans-form is greater than that of the cis-form, which indicates that the aggregates of the former in the liquid state are more unsymmetrically arranged than for the latter.

In a paper by L. Ebert (*Z. physikal. Chem.*, 1924, **113**, 1) an attempt is made to explain the significance of dielectric polarisation from the point of view of constitution. This author analyses the molecular polarisation P due to dipole molecules into that due to the electronic P_E, the ionic P_A, and the molecular orientation P_0, and indicates methods for their evaluation ($P - P_E = P_A + P_0$). $P_A + P_0$ is of great interest from the physico-chemical point of view, especially in explaining the association of molecules in the gaseous and liquid condition. Water and the alcohols give almost identical values for $P_A + P_0$ in the gaseous state, H_2O, 56·3 ; CH_3OH, 54·7 ; C_2H_5OH, 54·9, but in the liquid state, owing to the occurrence of dipole-association, the value for water is decreased to a much greater extent than for the alcohols. In general, it is found that the smaller the size of the dipole molecule the more strongly is it associated in the liquid condition. The orientation polarisation of molecules containing several dipoles is shown to depend on the molecular symmetry, being the higher the more unsymmetrical the molecule. Thus measurements of this property will possess a value for the determination of molecular symmetry. The orientation of molecules in an electric field, the Kerr effect, and the magnitude of the van der Waal constant a depend on $P_0 + P_A$. Further papers on this subject have appeared by Ebert (*Z. physikal. Chem.*, 1924, **114**, 430), G. Szivessy (*Z. Physik*, 1924, **26**, 323), and C. P. Smyth (*J.A.C.S.*, 1924, **46**, 2151).

GEOLOGY. By G. W. TYRRELL, A.R.C.Sc., Ph.D., University, Glasgow.

Stratigraphical and Regional Geology.—A large number of important memoirs on these subjects have come to hand recently. Prof. T. J. Jehu and Mr. R. M. Craig continue their studies on the geology of the Outer Hebrides with a description of South Uist and Eriskay (*Trans. Roy. Soc. Edinburgh*, liii, pt. 3, 1925, 615–41). These islands consist almost entirely of various gneisses and granulitic rocks belonging to the Archæan, and all of igneous derivation. A belt of varying width on the eastern side of the islands is affected by zones of shearing resulting in the production of flinty-crush phenomena to an extraordinary extent. The western side of this belt shows a striking development of flinty-crush rock, followed to the east by a broad zone of sheared and crushed gneisses. Numerous dykes of crinanite, quartz-dolerite, and lamprophyre intersect the gneisses along a N.W.–S.E. trend, and are therefore presumed to belong to the Cainozoic igneous episode.

The chief result of Mr. W. J. McCallien's study of the Tarbert district of Loch Fyne (*Trans. Geol. Soc. Glasgow*, **17**, pt. 2, 1925, 233–63) is the shifting of the present mapped boundary between the Erins Quartzite and the Stonefield Schists 1½ miles to the N.W. It is also shown that the Stonefield Schists become increasingly siliceous towards the boundary, and this is taken as indicating a passage to the conditions prevailing during the deposition of the Erins Quartzite. According to Mr. E. B. Bailey's interpretation, however, these rocks belong to different structural units and are brought together along a great line of movement.

The geology of Southern Guernsey is described by Mr. D. J. Farquharson (*Quart. Journ. Geol. Soc.*, **80**, pt. 3, 1924, 374–88). All the rocks are Pre-Cambrian, the oldest being the Jerbourg Schists of sedimentary origin, which are followed by several types of granitic and dioritic gneisses. At the south-western extremity of the island the Pleinmont shales and grit appear to have been deposited on an uneven floor of gneiss.

The new Survey memoir on the Pre-Tertiary Geology of Mull, Loch Aline, and Oban (*Mem. Geol. Surv., Scotland*, 1925, 140 pp.) deals with the crystalline schists, the sediments and lavas of the Old Red Sandstone, including the conglomerates and lavas of Oban and Kerrera, and the richly fossiliferous Mesozoic rocks of the region of which Mull is the centre. The latest Mesozoic formation consists of a few feet of white chalk, resting on white sandstones whose rounded and polished grains indicate desert conditions on the shores of the Chalk sea. This sandstone yields a first-rate glass sand at Loch Aline. The Ross of Mull granite is the only other material of economic importance in the district.

The detailed examination of the Lower Carboniferous rocks of the Settle area has led Prof. E. J. Garwood and Miss E. Goodyear (*Quart. Journ. Geol. Soc.*, **80**, pt. 2, 1924, pp. 184–273) to the conclusions that the whole of the succession developed north of the North Craven Fault belongs to the N.W. Province facies, and exhibits the same faunal succession as that previously determined for rocks of the same age in Westmorland. The strip of country lying between the Craven Faults is, for the greater part, characterised by the same type of development, and the Middle Craven Fault may therefore be taken as the southern limit of the N.W. Province facies. There are several minor points of difference when the West Yorkshire succession is compared with that of Westmorland. A gradual lateral change from the northern to the southern type of sedimentation and fauna can nowhere be traced. The change generally occurs abruptly along the line of the Middle Craven Fault. The problems of stratigraphical distribution and development may be best explained by postulating a general movement from the S. or S.E. against the rigid northern block comprising Ingleborough and the Craven Highlands, the actual lateral displacement being greatest along the margin of the South Craven Fault.

Prof. S. H. Reynolds and Dr. E. Greenly have described the remarkable structures in the Upper Palæozoic rocks of the Clevedon-Portishead area of Somersetshire (*Quart. Journ. Geol. Soc.*, **80**, pt. 3, pp. 447–67). The tectonics are stated to be of true Northwest Highland type, with a great thrust-plane itself bent into secondary undulations. Folding appears everywhere to be subordinate to thrusting.

In a discussion of the Calciferous Sandstone strata succeeding the lavas of that period in North Ayrshire (*Trans. Geol. Soc. Glasgow*, **17**, pt. 2, 1925, pp. 204–32) Mr. J. E. Richey shows that the lava land was partly submerged, and a gulf came into existence communicating north-eastward with the Renfrewshire basin of deposition. In this seaway the Calciferous Sandstone sediments were laid down. A large land area bordered it to the east, and probably also to the west. These conclusions are based on the geographical distribution of the limestones below the famous Hurlet seam. Subsidence of these lands resulted in marked overlaps of the higher strata over the lower, and notable variations of thickness ensued. The eastern land finally disappeared early in the Limestone-Coal Group times. The distribution of the overlap points to unequal subsidence of the land rather than to surface irregularities.

The Geological Survey memoir on the country around Wem (Shropshire) describes a region which is mainly occupied by Triassic rocks (*Mem. Geol. Surv., Expl. of Sh.* 138, *England*, 1925, 118 pp.). Structurally they form an elongated synclinal basin the axis of which runs S.W. to N.E. An outlier of Lias occurs at the N.E. extremity of the outcrop, and the Bunter Sandstones and Pebble-beds crop out as a rim around the margins of the basin.

Prof. W. S. Boulton describes the curious breccia-bed recently discovered by him underlying Nechells (Birmingham) and its relations to the red rocks of the adjacent district (*Quart. Journ. Geol. Soc.*, **80**, pt. 3, 1924, pp. 343–73). The breccia is mainly a coarse scree accumulation deposited on dry land, with intermittent washes of sand and marl swept down from the hill slopes by flood waters. It is believed to occupy the stratigraphical position of a large part of the Bunter Sandstone and Pebble-beds in the adjacent areas.

The Permian breccias of Arran have been studied by Mr. B. H. Barrett with a view to determining the sources of their materials (*Trans. Geol. Soc. Glasgow*, **17**, pt. 2, 1925, pp. 264–70). He shows that the pebbles were brought in by river floods from the north, east, and west, and that the sources were all comparatively near at hand.

Under the fascinating title of "The Desert Shores of the Chalk Sea," Mr. E. B. Bailey (*Geol. Mag.*, **61**, 1924, pp. 102–16) marshals the evidence for desert conditions over the British area during the Chalk period, basing his conclusions mainly on the Cretaceous sections in Mull and Morven, which show a fine millet-seed sandstone under the Senonian chalk bed, and pronounced silicification of the chalk itself. The latter is intersected by sand veins which carry rounded grains. Polished and rounded sand grains have also been found by various investigators in the white Chalk from Antrim to France. The purity of the chalk is ascribed to the lack of rain on the neighbouring land, resulting in an almost complete absence of terrigenous sediment.

The cycles of sedimentation and the history of the Anglo-Franco-Belgian Cainozoic basin are the subjects of argumentative papers by A. K. Wells and S. W. Wooldridge (*Geol. Mag.*, **60**, 1923, pp. 545–50) and Prof. L. D. Stamp (*ibid.*, **61**, 1924, pp. 98–102).

Dr. Th. Vogt has closely studied the transition between the Sparagmite system of South Norway with its non-fossiliferous, arenaceous, continental deposits, and the overlying marine deposits, the lower layers of which contain a rich Lower Cambrian fauna (*Norsk. Geol. Tidsskr.*, **7**, pt. 3, 1924, pp. 281–383). The main result of the work is that there is not a gradual transition between the two formations as previously thought, but a typical disconformity, of sufficient time-length to allow for the two zones of Lower Cambrian which are missing in the section near L. Mjösen. Vogt concludes that the Sparagmite system represents a Late Proterozoic series of sediments, which, however, is more closely related to the oldest Palæozoic formations than to the preceding Proterozoic system (the Jotnian), and is therefore to be considered as a transitional system.

The geology of Prince Charles Foreland, the long, narrow, mountainous island off the west coast of Spitsbergen, has been described by the writer (*Trans. Roy. Soc. Edinburgh*, **53**, pt. 2, 1924, pp. 443–78). The island consists mainly of Hecla Hook rocks, which are probably Cambro-Ordovician in age, and are correlated with certain rocks in North Norway and the Durness Limestone of the north-west of Scotland. Two of the three series into which the system is here divided show advanced cataclastic structures, due to great mechanical movement in an orogenic belt which is the continuation of the great Caledonian fold-mountain range of Scotland and Scandinavia. Rocks of Cainozoic age occur in a narrow eastern zone. They consist of coarse basal breccias resting on the Hecla Hook rocks, followed by thick sandstones and shales. This series is downfaulted towards Foreland Sound, and as an exactly reciprocal structure has been found on the opposite (mainland) side, Foreland Sound appears to be a trough or graben which has subsided below sea-level.

Prof. O. Holtedahl's expedition to Novaya Zemlya in 1921 has been fruitful in stratigraphical results (" Report on the Scientific Results of the Norwegian Exped. to Novaya Zemlya, 1921," *Vidensk.-selsk. Kristiania*, 1924, 183 pp., 44 plates). The oldest rocks contain fossils of Ozarkian age. The existence of Silurian rocks is doubtful, and at any rate there are no signs of unconformity below the Devonian in this region. The Lower and Middle Devonian is represented mainly by limestone and dolomite, and is very fossiliferous. It is followed by sandstones and shales with volcanic zones, belonging to the Upper Devonian. Highly fossiliferous Lower Carboniferous limestones also occur, followed by rocks in which the fossils resemble those of the Artinskian horizons of Russia. The whole series was highly folded in the Hercynian deformation of Late Palæozoic times.

The value of the work is greatly enhanced by a very thorough discussion of the Palæozoic stratigraphy of Arctic lands, based on the accumulated recent literature. This has led to wide generalisations of which the most important is perhaps the discrimination of two main systems of geosynclines and folding-zones ; an East America–West European–Arctic (or Atlantic-Arctic) system, and a West American–East Asiatic–East European (Pacific-Arctic) system.

An important discovery by T. T. Quirke indicates that some of the so-called Grenville formation between the typical Huronian region and the Bancroft-Haliburton district of Ontario should be relegated to a much higher horizon (*Journ. Geol.*, **32**, 1924, pp. 316–35). In this region Huronian sediments can be traced into metamorphic rocks of the distinctive Grenville type ; and with them are amphibolites which are due to the metamorphism of Keweenawan diabases. Hence, too, the batholiths which cut the " Grenville " schists and gneisses must be regarded as of Post-Huronian rather than of Pre-Huronian age, as heretofore.

The description of the fine collection of fossils and rocks from Somaliland, made by Messrs. B. K. N. Wyllie and W. R. Smellie under the auspices of the A.P.O.C., and the geological results obtained therefrom, form the subject of the first monograph of the Geological Dept. of the Hunterian Museum of Glasgow University (*Mon. of the Geol. Dept., Hunt. Mus., Glasgow Univ.*, No. 1, 1925, 180 pp., 18 plates). Somaliland, the north-eastern horn of Africa, is geographically unique as

Africa's only great peninsula. Prof. J. W. Gregory has edited the volume, and has contributed an introduction on the geology of the country and its relation to the great Rift Valley system of East Africa. Somaliland consists of a foundation of gneiss, which is covered by marine Jurassic and Cainozoic limestones, the Cretaceous Nubian Sandstone, and by lavas of at least two distinct geological periods. Messrs. Wyllie and Smellie have written an account of their geological traverses across the country, and specialists have described the several groups of fossils.

In a memoir dealing with the geology and physical geography of Chinese Tibet with reference to the mountain systems of S.E. Asia, the results of their recent expedition, Prof. J. W. Gregory and Mr. C. J. Gregory (*Phil. Trans.*, Ser. B, vol. 213, 1925, pp. 171–298) describe a long succession of stratified and igneous rocks, ranging from the Eozoic to the Pleistocene, in which only the representatives of the Cambrian, Jurassic, and Cretaceous formations are missing. The geological structure of Chinese Tibet and the adjacent districts of eastern India is complicated by the superimposition of at least three systems of folding : the earliest in the Pre-Cambrian mainly of meridional trend ; the second of Hercynian age, which has produced the Indo-Malayan mountain-system striking N.N.W.–S.S.E.; and the third the Himalayan system of approximately E.–W. direction. The evidence favours the suggestion that the Himalayan folding crossed the lines of the older Hercynian folds in Chinese Tibet. Inliers of older rocks occur in series trending west and east, and, although greatly influenced by the Hercynian structure, they occur in positions consistent with their uplift along axes of Himalayan direction.

A symposium on the correlation of the Tertiary formations of S.E. North America, Central America, and the West Indies, with the Tertiary formations of Europe, has been held by the Geological Society of America, under the presidency of Dr. T. W. Vaughan (*Bull. Geol. Soc. Amer.*, 35, 1924). In his presidential address (*ibid.*, pp. 677–742) Dr. Vaughan discussed the criteria and status of correlation and classification of Tertiary deposits in general, including therein a masterly statement of principles and a criticism of the Lyellian method of correlation, and giving some valuable correlation tables of European and American Tertiary formations. W. D. Matthew followed with a discussion of the Tertiaries of the Great Plains (*ibid.*, pp. 743–54), which he hopes will be of service in reconciling the evidence of vertebrate faunas with that of marine invertebrates and plants. The remaining nine papers of the symposium all deal with various palæontological aspects of the Tertiary formations.

The British Virgin Islands, according to Mr. K. W. Earle, (*Geol. Mag.*, **61**, 1924, pp. 339–51), consist of rocks of igneous and metamorphic nature, with accumulations of pyroclastic rocks, breccias, and agglomerates. The igneous rocks consist of granodiorites, diorites, and gabbros, with various types of dykes, and lavas consisting of augite-andesite and basalt. The metamorphic rocks are mainly altered sediments probably of tuffaceous nature, and often interbedded with volcanic breccias and agglomerates. These sediments are probably of Cretaceous age, whilst the igneous rocks belong to the Cainozoic. The geological structure of the islands correlates them indisputably with the Greater than with the Lesser Antilles.

Linked with the foregoing to some extent are the following two works, which are too detailed to be adequately summarised here: A. Deussen, " Geology of the Coastal Plain of Texas West of Brazos River," *Prof. Paper, U.S. Geol. Surv.*, No. 126, 1924, 151 pp., 36 plates; W. P. Woodring, J. S. Brown, and W. S. Burbank, " Geology of the Republic of Haiti," *Geol. Surv. Haiti*, 1924, 631 pp., 39 plates.

H. von Ihering's paper on Die Kreide-Eocän Ablagerungen der Antarctis (*N. J. f. Min.*, B.–B., **51**, 1924, pp. 240–301) is a useful summary of the Cretaceo-Eocene deposits, mainly of the American sector of Antarctica.

J. G. Andersson has written a valuable review of the Cainozoic deposits of Northern China in a volume of essays on that subject (*Mem. Geol. Surv. China*, Ser. A, No. 3, 1923, 152 pp.).

Sedimentary Rocks.—A. Heim presents a thorough discussion of submarine denudation and chemical sediments (*Geol. Rundschau*, **15**, 1924, pp. 1–47). He proposes a number of new technical terms for the various phases of subaerial and subaquatic denudation, and discusses the origin of greensands, radiolarian ooze, deep-sea clays, and marine limestones. An important conclusion is that many discontinuity planes in marine sediments are due to certain subaquatic processes, and not to emersion and transgression.

A massive work on the deep-sea deposits of the Atlantic Ocean prepared under the direction of the late Sir John Murray, and with a discussion of the results by Mr. J. Chumley, has recently been published (*Trans. Roy. Soc. Edinburgh*, **54**, pt. 1, pp. ix, 252). No less than 1,426 samples collected during thirty-five cruising expeditions between 1857 and 1911 are fully described. Mr. Chumley has distinguished eleven types of deposit, which, in order of frequency, are globigerina ooze, blue mud, red clay, volcanic mud and sand, pteropod ooze, green mud and sand, coral mud and sand, diatom ooze, red mud, calcareous sand, and radiolarian ooze. Transitional deposits; and the rare cases in which stratification is shown in the samples, are discussed, as well as the organic and inorganic materials which enter into the composition of the Atlantic bottom deposits as a whole.

In a paper on the origin of the sedimentary iron ores, G. Berg (*Geol. Rundschau*, **15**, 1924, pp. 97–109) shows that in all kinds of marine and continental iron-ore sedimentation there is a gradual variation in the nature of the sediment with decreasing oxygen-content of the medium from which the deposition takes place, and also with the iron-concentration of the solutions.

In his second Presidential Address to the Liverpool Geological Society, Prof. P. G. H. Boswell presents some further considerations on the petrology of sedimentary rocks (*Proc. Liverpool Geol. Soc.*, **14**, 1924, pp. 1–33). He reviews the circumstances by which the distribution of heavy minerals in British sediments is influenced, and shows that the variety of minerals is greatest at periods of orogenetic movement. Methods of description of the minerals are considered, as also the range of minerals in geological time, and the evidence provided by them regarding the climatic and physiographic conditions under which the deposits were laid down.

Prof. Boswell has also described the petrography of the sands of the Upper Lias and Lower Inferior Oolite in the West of England (*Geol. Mag.*, **61**, 1924, pp. 246–64). The deposits are of neritic facies, and possess a characteristic and peculiar mechanical and mineral composition. There is a general constancy of grade, mostly very fine sand grade. The sands are blue and glauconitic in depth. They contain an abundance of angular brown-pink to colourless garnets (possibly derived from rocks like those of the Lizard). Micas, too, are abundant, together with chlorite, chloritoid, kyanite, staurolite, orthoclase, and microcline. The abundance of titanium minerals is characteristic of the deposits. The sands differed markedly in petrology from the Palæozoic rocks of Wales and the West Country, from the Triassic, and from the Cretaceous and Eocene of Devonshire and Dorset. It is concluded that the Lias-Inferior Oolite sands have been derived from the south or south-west, and from rocks like those of western Brittany.

A study of the microstructure of South Wales anthracite by A. Stuart (*Geol. Mag.*, **61**, 1924, pp. 360–6) has led to the conclusion that the same materials have contributed to the composition of anthracite as to the bituminous coals. Loosely packed cells and large intercellular spaces testify to plants of a swampy environment. The megaspores and cells show no signs of having undergone undue pressure, and it is therefore difficult to believe that the coal has originated by the compression of a mass of vegetation many times the present thickness of the seam. Hence Mr. Stuart turns to the concept of a viscous fluid as the parent of coal, in which plant remains were gradually carbonised, and in which solidification through increasing viscosity took place before the deposition of much sedimentary material above it. The flow structures which have been demonstrated in the coals are understandable on the hypothesis of a semi-fluid mass.

" Paraffin dirt " is a curious form of clayey soil found in the Gulf Coast region of Texas and Louisiana, which has a peculiar rubbery, curdy, resilient character when wet. It has been thought to be of significance in locating concealed oil and gas pools. Mr. H. B. Milner (*Mining Mag.*, **32**, 1925, pp. 73–85) has little difficulty in demonstrating that it is a true soil in all respects, and differs in no fundamental structure or in mineral composition from other soils. It contains a large amount of colloidal organic matter and is strongly adsorptive, but it is not paraffinaceous, and not a residual product of inspissated petroleum. Its resilience is connected with its adsorptive powers for fluids and gases, and its connection with petroleum is believed to be largely fortuitous.

J. V. Lewis's paper on the fissility of shale and its relation to petroleum (*Bull. Geol. Soc. Amer.*, **35**, 1924, pp. 557–90) contains some valuable material on the nature and origin of clay and shale, and on the development of fissility in argillaceous rocks. The mechanical basis of fissility in shale is the parallel arrangement of flat and elongate constituents. These are partly original materials, but in general they are mostly of secondary origin. The force producing the structure is gravitational compression, resulting in the flattening of soft particles and flocculent aggregates, the orientation of flat constituents into parallel horizontal arrangement, and leading to the development of flaky secondary kaolins and hydromicas. Plastic flow of the sediment is also an aid in the parallel arrangement of the constituents.

PLANT PHYSIOLOGY. By Prof. Walter Stiles, Sc.D., University College, Reading (Plant Physiology Committee).

Irritability and Movement in Plants.—Research on movement in plants has been pursued vigorously since this subject was last reviewed in these pages three years ago, so that only a selection of the more representative and important contributions can be referred to in this review.

Further investigations on contact stimulation have been made by P. Stark (" Weitere Untersuchungen über das Resultantengesetz beim Haptotropismus. Mit besonderer Berücksichtigung physiologisch nicht radiärer Organe," *Jahrb. f. wiss. Bot.*, **61**, 126–67, 1922). In coleoptiles, which are usually elliptical in cross-section, it was found that if the narrow and broad sides are subjected to equal stimulation by stroking, the resultant curvature is in the direction of the broader side. This is probably due to the structure of the coleoptile, the mechanical resistance to movement being less in the direction of the broad side. The reaction to contact stimulation was studied particularly in the markedly dorsiventral petioles met with in the genus *Clematis*. Here Stark was able to make out three types of reaction : the *recta*-type, in which the upper and under sides react equally strongly, but less strongly than the flanks ; the *paniculata*-type, in which the under side reacts more strongly than the flanks and these more strongly than the upper side ; and the *Vitalba*-type, in which the flanks respond most strongly, the under side a little less intensively and the upper side least strongly.

An interesting observation on reaction to contact in *Gymnopetalum* has been made by P. M. Debbarman (" Some Observations on the Anchoring Pads of *Gymnopetalum cochinchinense* Kurz, and some other Cucurbitaceous Plants," *Journ. Indian Bot.*, **3**, 52–7, 1922). It was observed that if a tendril of this plant comes into contact with a large, rough, flat surface around which it cannot coil, the epidermal cells in the neighbourhood of the place of contact develop into very thin-walled papillæ which, by rapid development of transverse walls, form linear hair-like structures. These, by entering into crevices of the surface, serve to bring the tendril into close contact with it.

Experiments to test the contact irritability of root-hairs of a number of species belonging to eleven different families have been made by K. Seidel (" Untersuchungen über das Wachstum und die Reizbarkeit der Wurzelhaare," *Jahrb. f. wiss. Bot.*, **63**, 501–52, 1924). In all the species examined it was concluded that the root-hairs exhibit no thigmotropism, but that all observations which might appear to indicate contact irritability can be explained on account of rapid growth and the plasticity possessed by the membrane at the tip of the root-hair.

The hydrion theory of geotropism propounded by Small has been subjected to severe criticism from a number of different quarters. Various assumptions made by the theory have been criticised by V. H. Blackman (" The Theory of Geotropic Response," *New Phyt.*, **20**, 38–42, 246–7, 1921) and R. Snow (" The Hydrion Theory of Geotropism," *New Phyt.*, **20**, 247–8, 1921), while a number of different workers have failed in attempts to produce the reversal of geotropic response in stems and roots by exposure to acid and alkaline vapours respectively, such a reversal forming the experimental basis of Small's theory. Thus, F. C. Newcombe (" The Supposed

Reversal of Geotropic Response," *New Phyt.*, **22**, 281–8, 1923), after an attempt to repeat Small's experiments, considers that Small's conclusions in regard to reversals of direction were due to "misinterpretation of distortion figures and to the behaviour of sagging shoots, too old and too weak to hold themselves erect." The conclusion of N. Cholodny ("Zur Frage nach der Rolle der Ionen bei geotropischen Bewegungen," *Ber. deut. bot. Ges.*, **41**, 300–11, 1923) from experiments carried out with *Helianthus* seedlings in atmospheres containing relatively large proportions of carbon dioxide, is that the supposed reversal of the normal ageotropic curvature in the stems is really a passive sinking down of the seedlings, and that in general the curvatures observed by Small and his collaborators are the result of pathological changes due to the abnormal conditions to which the seedlings were exposed. Similar results and conclusions are also recorded by R. E. Chapman, W. R. I. Cook, and N. L. Thompson ("The Effect of Carbon Dioxide on the Tropic Reactions of *Helianthus* Stems," *New Phyt.*, **23**, 50–62, 1924), by Anna A. Haire ("Attempts at Reversal of Geotropic Response," *Papers Michigan Acad. Sci. Arts and Letters*, **3**, 111–22, 1924), and by W. Allen ("De l'influence du gaz carbonique sur le géotropisme," *Comp. rend. soc. biol.*, **90**, 1447–8, 1924).

In a continuation of work on the geotropic reaction in ferns Miss T. L. Prankerd and Miss F. M. O. Waight ("On the Presentation Time and Latent Time for Reaction to Gravity in Pteridophytes," *Rep. Brit. Ass., Hull Meeting*, 1922, p. 397; see also *Ann. Bot.*, **37**, 55–61, 1923) have attempted to determine the range of intensity of gravitational irritability in the fronds of *Asplenium bulbiferum* by finding the presentation time under different conditions. It is found that the fronds of this fern exhibit a grand period of irritability to gravity as measured by presentation time, this period corresponding with the stage of development of the frond and not directly with its age or size. At 20° C. and 85 per cent. humidity the presentation time decreases from 8 hours at a very early stage of development to a minimum of half an hour when the fifth to seventh pairs of leaflets are unfolding. With further development the presentation time increases up to about 6 hours a little before the frond is mature, when response to the gravitational stimulus ceases. The latent time also varies with the stage of development of the frond, but to a much less extent than the presentation time, the range being from 16 to 5 hours.

Some important contributions have been made on the subject of phototropism, chiefly in reference to Blaauw's theory that phototropic curvature is due to the different rates of growth of the two sides of an organ resulting from the different intensities of illumination to which the two sides are exposed. L. Brauner ("Lichtkrümmung und Lichtwachstumsreaktion," *Zeitschr. f. Bot.*, **14**, 497–547, 1922) carried out experiments on the coleoptile of oat from this point of view. A metal filament lamp was used as source of light and parallel series of experiments were performed in which growth and phototropic curvature were measured. In the experiments on the influence of light on growth the plants were illuminated by means of two mirrors facing one another, and in the experiments on phototropic curvature by one mirror only; in both cases the light fell perpendicularly on the surface of the plant axis. Good agreement was found between growth-reaction and curvature in the two series of experiments. The region of response is the uppermost 10 mm. of the coleoptile, although if response is artificially prevented in this region the basal part of the organ will react. Brauner supposes that the permeability of the cells is increased by illumination so that on the more illuminated side the conduction of growth-inhibiting substances is facilitated with the result that on the illuminated side growth is retarded and curvature results in the direction of the source of light. By the use of an electrical conductivity method the same worker subsequently showed that the permeability of the cells of the *Avena* coleoptile does actually increase as a result of illumination ("Permeabilität und Phototropismus," *Zeitschr. f. Bot.*, **16**, 113–32, 1924). From the results of a series of experiments also carried out on the coleoptile of *Avena* in which curvatures and growth under one-, two-, and four-sided illumination were observed, O. Renner ("Die Wachstumsreaktionen bei Licht- und Schwerkraftreizung," *Zeitschr. f. Bot.*, **14**, 449–62, 1922) also considered that he had obtained evidence in support of Blaauw's theory of phototropism.

Opposition to Blaauw's theory comes from H. Lundegårdh ("Ein Beitrag zur quantitativen Analyse des Phototropismus," *Arkiv f. Bot.*, **18**, 1–62, 1922). The experimental material was again the coleoptile of *Avena*. It was found that with increasing quantity of incident light energy a maximum reaction was obtained with a light quantity of 10 lux-seconds. With further increase in light quantity a minimum reaction was obtained at about 4,000 to 10,000 lux-seconds and a second maximum at about 2 × 10^6 lux-seconds, the response again decreasing with further increase in the value of the stimulation. These results cannot be explained on the view that the curvature results from independent growth reactions in different regions of the coleoptile, and it is held that the direction of the curvature is determined by the direction in which the incident light penetrates the reacting organ. Lundegårdh considers that the curve relating intensity of response with intensity of stimulation is to be regarded as the resultant of two curves, one in which the response is positive and the other in which it is negative, having different thresholds of stimulation, but of similar course.

Among researches dealing with chemotropism may be mentioned those of W. Mevius on *Drosera rotundifolia* ("Zur Chemonastie von *Drosera rotundifolia*," *Biochem. Zeitschr.*, **148**, 548–65, 1924). Leaves of this plant were placed in solutions of various salts in a number of different concentrations and the effect on the tentacles observed. Thus in a solution of sodium chloride with a concentration of N/40 or lower the tentacles bend over and then return to their original position, while in higher concentrations of the salt the tentacles remain bent. The nitrates of potassium and sodium were found to be more effective than the iodides, bromides, and chlorides, while these were more effective than the sulphates.

In the work of Seidel on root-hairs referred to above, it was found that the root-hairs of most of the species examined showed positive chemotropism when stimulated by great excess of some particular ion. Thus members of Polygonaceæ and Chenopodiaceæ were found to be very sensitive to phosphates, the Caryophyllaceæ to nitrates, and the Gramineæ to ammonium salts. The relation between intensity of stimulation and intensity of response was found to obey Weber's law, while no negative chemotropic curvature was observed in high concentrations of dissolved substances.

So-called autonomous movements have been described by W. T. Saxton in the case of the lateral leaflets of *Eleiotis soraria* ("Autonomous Movements in *Eleiotis soraria* D.C.," *Journ. Indian Bot.*, **3**, 72–8, 1922). They possess a movement of the same type as that of the leaflets of *Desmodium gyrans*, having a longitudinal amplitude of about 140° and an amplitude of rotation of the petiole of about 30° to 100°, thus moving in a curve of which the orthogonal projection approaches an ellipse in form. A complete rotation occupies about two minutes. At the same time as the leaflets are carrying out this movement they are also undergoing a rotational oscillation on their own axes. The movements differ from those of *Desmodium gyrans* in one important point, namely, that the movement along the major axis of the curve is chiefly due to curvature of the distal end of the stalk of the leaflet and only to a much less extent to curvature of the proximal end.

A reinvestigation of the influence of the electrical conductivity of the air on the so-called sleep movements of the leaves of *Phaseolus multiflorus* has been made by E. Scheidler and A. Sperlich ("Die Bewegung der Primärblätter bei etiolierten Keimpflanzen von *Phaseolus multiflorus*," *Zeitschr. f. Bot.*, **14**, 577–97, 1922). By contemporaneous registration of the leaf movements and of the conductivity, and by artificially altering the conductivity of the air, they succeeded in showing, contrary to the opinion formerly expressed by Rose Stoppel, that the periodic movement of the leaves has nothing to do with the conductivity of the air. The movements must still be regarded as autonomous.

Finally, reference may be made to two papers dealing with the transmission of excitation through the plant. In one of these Helen A. Purdy ("Studies on the Path of Transmission of Phototropic and Geotropic Stimuli in the Coleoptile of *Avena*," *Kgl. danske Vidensk. Selsk., Biol. Medd.*, III, 8, 1–29, 1921) sought to determine whether the transmission of the phototropic stimulus from the illuminated tip to the shaded base of the coleoptile of *Avena* is limited to a definite restricted path. A transverse incision was made between tip and base of the cotyledon, thus separating the upper and lower portions of the organ through about a third to a half of the cross section. In the incision a piece of platinum foil was inserted. It was then found that a marked transmission of the excitation took place when the coleoptile was illuminated on the side of the incision, but that when illuminated on the side away from the incision transmission of the excitation was only slight. It was therefore concluded that transmission of the excitation takes place chiefly in a longitudinal direction on the side remote from the source of light, and it was pointed out that the results agree with the theory that the transmission of excitation is brought about by the diffusion of one or more substances from the place of reception of the stimulus.

The second paper on transmission of excitation to which reference should be made is one by R. Snow ("Conduction of Excitation in Stem and Leaf of *Mimosa pudica*," *Proc. Roy. Soc.*, B, 96, 349–74, 1924). This worker repeated experiments made by Ricca and agrees with him that the conduction of excitation in the stem of *Mimosa pudica* is normally brought about by the movement of a stimulant in the water of the xylem. He considers, however, that another form of conduction ("high-speed conduction") is also present. The stem stimulant appears not to be a protein, and it will diffuse through a collodion membrane. It is held that conduction in the leaf takes place normally in the phloem, and the pulvinus is considered to be the place where the path of conduction changes over from xylem to phloem, for in this region solutions can pass readily from one tissue to the other.

ARTICLES

THE MEASUREMENT OF SOLIDITY

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A PERUSAL of the histories of Physics, Chemistry, or General Mechanics will show that the earliest stage of a science is necessarily characterised by loose writing; at a later stage more distinct meanings are assigned to the terms employed, and writers must perforce become more cautious, as statements which are intelligible can be disputed, and rejected if they are found to be false. At a still later stage quantities are defined and measured, and in this last stage the utility of a science is enormously increased. The bounds now set to all the constructional arts are those imposed by our knowledge of solidity, so it behoves us to reflect on the principles of measurement and their particular application to the internal mechanics of solid bodies. The subject is an eminently utilitarian one, as our use and control of natural phenomena is strictly proportioned to the degree in which we understand them.

Solidity, as has been said of Electricity, " is not a thing like St. Paul's Cathedral, but is a way in which things behave." Solids resist deformation, and the word " solidity " is here intended to cover the kinds, degrees, and attendant circumstances of resistance. There is no settled terminology, and the words " consistence " and " firmness " seem equally suitable.

The phenomena of solidity are as follows: To any assigned mechanical action or stimulus a solid gives definite characteristic reactions of mechanical and other types. Electrical, magnetic, and optical reactions are frequently met with, but are customarily relegated to the particular sciences concerned; thermal reactions are universal and may conveniently be classed as mechanical. A series of solids can always be found which react in gradually varying degree to any assigned stimulus, and the reaction of a single solid varies progressively as the stimulus is modified in any particular manner. Solidity is therefore a continuum of related quantities, such as is commonly met with in all branches of physical science. The causes and origins of solidity are quite foreign to the present subject, which is defined as the mode of action of solidity.

Experience suggests the propriety of dealing with the simpler forms first. A "solidity" here implies a uniform solidity, and the properties of organic tissues, stratified rocks, and single crystals are not now in question. A reasonable regard for proportion is necessary. The superficial parts of the earth transmit force in much the same way as steel does, but even in a small part of the earth—as at Beachy Head—one may find contiguous portions having widely different mechanical characteristics. Bodies like the industrial metals, massive rocks, glass, clay, rubber, and so on, present the type of solidity now referred to. Two specimens of any such body, when scrutinised closely, may be seen to exhibit a diversity and lack of correspondence in their parts, although the specimens may be indistinguishable by mechanical experiment. Moderately fine-grained solid bodies thus have a characteristic solidity of their own, distinct from the solidities of their components.

The measurement of any group of entangled phenomena involves two acts of mind; first the selection of quantities, and second the establishment of scales. A satisfactory choice displays the whole as a limited number of intelligibly related concepts; the machinery of mathematics then carries the inquirer past all obstacles, into regions quite inaccessible to the unaided intellect. The process, and its importance, may be illustrated by the examples of space and electricity.

Automotive creatures like ourselves have paid the closest attention to space throughout the whole course of our development. Lengths and angles can be estimated by the eye and recorded in the memory, and evenly-divided rigid scales are so readily constructed that no other kind suggests itself. Extreme familiarity makes it difficult to imagine a wrong choice of elements, or the use of arbitrary and irregular scales; either mistake, however, would clearly have been fatal to the metrical comprehension of space. Geometry is indispensable to all the arts, and, where yardstick and quadrant are unknown, man still disputes his cavern with the bears.

We have no eyes for electrical magnitudes, so the subject was developed at a much later date. In illustration of the methods which have proved successful it may be noticed that, about a hundred years ago, two distinct elements in a simple electrical system were found to retain a constant proportion irrespective of changes in a third element; the accumulated chemical action was found to bear a fixed relation to a mechanical attractive force, and alterations of "resistance" did not disturb the proportion. The abstract conception of "current" was thus established as an intelligible, if inexplicable, reality, and at the same time a rational scale for this quantity was determined. Prior to the conception of "current," electricity was a toy for the curious: afterwards, and in a comparatively short period, it has become an indispensable adjunct to civilised life.

An historical example in chemistry and a hypothetical one in physics will show that mere experimenting does not make a science. The records of Alchemy are lost, and need not be regretted. The experiments of Dalton, Gay-Lussac, and Avogadro were no more accurate than those of their predecessors, but they were better regulated, and have fructified very differently. Incidentally we notice that the honest part of alchemy was confounded with dishonest mysticism, and that sciences which cannot justify themselves are still mistrusted.

Suppose—as an alternative to the electrical procedure which has been recounted—that an instrument had been devised giving an indication of what can now be recognised as some moderately complex function of current and terminal voltage. The scale of such an instrument could only be divided arbitrarily, and a given reading might include either a large current or a small one. The instrument's readings, though clear and precise, would serve neither for the ascertainment of electrical facts—as we require to know them—nor for the advancement of electrical knowledge. Complexes of the kind in question are not subject to the rule that twice one are two, and, in short, are quite unintelligible. The electrical, chemical, and optical industries owe their existence to pioneers who strictly abjured this kind of quantity.

The relative value of rational and random experimenting is admirably shown in the history of solidity. Measurement began with metals. In the early days of iron and steel the quality of the material was very variable, and technicians found it prudent to submit specimens to mechanical operations which roughly imitated the more important conditions of co-temporary use. The employment of these "tests" has persisted, and the system has spread to other industries, but the more diverse and exacting requirements of recent times have shown that "tests," when not strictly imitative, are generally misleading. For this, or some other reason, new "tests" are constantly being added to the old ones. The literature of industrial "testing" has become considerable, but the so-called "practical" tests have little influence on engineering practice, except in so far as uniformity of reaction is relied on as indicating uniformity of solidity. In this respect the "tests" fall short of their intended object, as—with one exception—their indications are complexes strictly analogous to the electrical complex recently mentioned. Some of the " tests " are frankly irrational, and the reaction is expressed as so many " blows " or " bends " ; in others, like the " tensile test," the reaction is misnamed, and given a spurious semblance of rationality. The single important exception is the Wöhler type of experiment, in which the action is repeated many millions of times. Here the reaction is legitimately expressed in rational terms—as a stress—and it is significant to note that, despite its more facile competitors, this type of experiment is now becoming regarded with increasing confidence and favour.

A very limited number of rational experiments has proved of greater service to engineers than the whole bulk of " testing " literature. The experiments in question showed that many important solids are characterised—in part—by two distinct elastic constants. This discovery has led to a highly developed analytical theory of elasticity, which makes no claim to being a complete guide to the practical employment of solids in engineering, but is an invaluable guide, and the only rational guide available.

The part played by " tests " in the design of structures is negligible, and " tests " afford little, if any, guidance in the manufacture of improved materials. The improvement of design and material is based almost entirely on repeated full-sized experiment, which is perhaps satisfactory for small articles but quite inapplicable to large ones. The result may be seen by comparing, say, the structure of a steamship with the chassis of an automobile. The construction of steel vessels is governed by Lloyd's—or equivalent—Rules, and from time to time the " action " specified in Lloyd's tests for ship plates has been amended with the object of defining it more closely. The " reaction " stipulated for has remained unaltered since the Rules were first published in 1889, whereas automobile steels, in a much shorter period, have improved almost beyond recognition. This illustrates what may be termed the language difficulty. Measurement is an extension of language, and " tests " are a rude substitute for measurement. It has been seen that intelligible ideas cannot be conveyed by the clatter of " tests," but this, nevertheless, is the only means of communication between engineers and their purveyors. Ship designers, metallurgists, and the Insurance Societies have seemingly discussed improvements for thirty-six years—with no result.

The contrast between the " test " language and English may be seen in the following sentences :

1. Strength is measured by rigidity.
2. Mildness is measured by the ratio of the elasticities.
3. The harder variety of the same substance is the more brittle.

In English these are propositions with a semblance of truth. The technical language should elaborate and refine the colloquial, and the first word in each sentence admittedly relates to a property of great importance; technology, however, cannot adjudicate, as the words employed have no fixed place in the technical vocabulary.

Lloyd's, the Engineering Standards Association, and other authorities, appear to have had difficulty in formulating an adequate specification of the "action" which constitutes the basis of the more important tests, and the less important ones are nowhere authoritatively defined; the "reactions" have been seen to be expressed in irrational terms, and most of the "tests" are applicable only to a very restricted range of solids. In these circumstances it is not surprising that only a few local and empirical relations have been found between the several test reactions. Nothing more, indeed, seems to have been looked for, and the most powerful instrument of progressive thought—induction—is thus lost to mechanics. "Test" records will join those of alchemy, and will not be preserved by our successors.

The lack of mechanical discriminants of a satisfactory kind has led to the adoption of distinctions in other—and really irrelevant—categories. An engineer is concerned in how a tool cuts, and not in what it contains, but engineering specifications usually include chemical clauses. A metallurgist's main concern should be to comply with specified mechanical requirements, but metallurgists rely largely on a merely descriptive science—a kind of metalline botany—in which appearances are only empirically connected with the realities of mechanics. Metallography, like chemistry, is indispensable to process-control in a factory, but photographs of speckled discs are inadmissible as evidence of things purely mechanical.

Microscopical study, however, has greatly increased our knowledge of solids, and it has long been recognised that a normal solid body is a "foam-structure" of the kind described by Quincke [1], comprising a collection of irregularly shaped crystalline, vitreous, or "intermediate" masses, commonly of diverse size and composition, and separated by films of a different material, which, in metallic solids, is usually vitreous. When such a body is deformed without fracture the deformation must be shared, without fracture, by all the components. Sir James Ewing and Dr. Rosenhain [2] discovered that the first visible indication of internal damage was usually a slipping—in parallel planes—of certain individual crystals. A different type of damage—separation of adjoining crystals—was discovered later.

Knowledge of the simple materials found in metallic foam-structures stands as follows. Sir George Beilby [3] devoted particular attention to the vitreous components, whose formation seems to be a special example of the phenomenon called dilatancy [4]. Purely vitreous metals, however, have not yet been made in masses large enough to permit of the quantitative ascertainment of their properties. The study of the mechanics of crystals was begun by Herr Voigt some forty years ago, but, as regards metals, this work is almost irrelevant, as the crystals examined were all of the brittle " mineral " variety. Ductile crystals—of ice—were studied by Mr. J. C. McConnel [5] at about the same time, but substantial knowledge of them dates from 1923, when Prof. Carpenter [6] produced aluminium crystals of a size convenient for mechanical experiments. Only a few kinds of metallic crystal have yet been examined ; their properties are surprising, but it is not now necessary to consider them. It is sufficient to emphasise that —from the point of view of rational mechanics—practically nothing is known of any of the simple bodies which are contained in ordinary conglomerate solids ; nothing is known of the attachments between these simple bodies, and the spatial relations of a distorted foam-structure are quite beyond the reach of mathematics. To attempt, in this roundabout way, to arrive at the mechanical properties of composite solids would be merely fantastic, and it is clear that descriptive metallography can have no practical bearing on the measurement of solidity. All the non-mechanical properties of solids are customarily measured without any reference to the details of foam-structure.

In regard to the bearing on our subject of recent work with the X-ray spectrometer, it may be observed that, when sufficiently large crystals are available, their mechanical properties —their solidity—can be ascertained by direct mechanical experiment, and cannot be ascertained in any other way. The result of combining a knowledge of crystal solidity and of the atomic arrangement which gives rise to it would be a further knowledge of the properties of atoms. The consequences of such further knowledge can scarcely be foreseen, but one interesting result would be an indication of how far our present solids fall short of the best that could be constructed with the atoms available.

Mathematical analysis is not altogether baffled by complexities in its subject-matter, and, as may be seen in the science of thermodynamics, it is often possible to deal with probabilities and averages, although individual incidents are unknown or even unknowable. The thermodynamics of solids is ill-developed. Physical science can naturally make no use of the kind of measurement which is favoured by technology, and science has been obliged to proceed independently; giving what it can to industry and getting nothing in return. The finer shades of solidity which are of primary technical importance are of only secondary interest to physicists, to whom the subject is thus both difficult of approach and without any special attractions. The thermodynamic theory of solidity, in its present form, covers little more than the relations between the properties of atoms and those of solid bodies composed of atoms of one kind. Rigidity—the essential property which distinguishes solids from other bodies—has only a small place in the theory, and mildness—or capacity for gross distortion—has no place at all. A panoramic view facilitates detailed survey, but such a view has not yet been obtained.

The thermodynamic theory, as now developed, is a science of origins and thus foreign to our purpose; thermodynamic data, however, suggest some interesting conclusions. It has been found that many of the mechanical properties—and even test reactions—of elementary solid bodies resemble their chemical and other properties in being irregular periodic functions of the weight—or serial number—of the atom concerned [7]. Things which are periodic functions of the same thing may well be simple non-periodic functions of one another, and the expectation is confirmed, for example, by the supposed proportionality of atomic heat and thermal expansion [8].

It has been found also that, for solid bodies generally, the coefficient of expansion is closely related to resistance to mechanical distortion [9]. If a number of bodies be ranged in order of "hardness" they are found to be in inverse order of expansion; the harder variety of one and the same substance expands less than the softer; crystals harder in one direction than another expand correspondingly; all normal solids become softer, and expand faster, as their temperature rises, and become harder and contract less as the temperature falls. The relation is independent of the kind or kinds of atom concerned, and of the physical category of the body. It thus appears, as was premised in the introduction to these notes, that relations do, in fact, subsist between what seem to be wholly unconnected elements of solidity. The atoms and molecules eliminate themselves from these relations, and solidity thus appears to be distinct from substance in a wider sense than is recognised in the current doctrines of isomerism and polymorphism. It further appears that solidity, when analysed, may become a convenient basis of physical reference, and that qualities now regarded and written as attributes of substance may more conveniently, and more properly, be regarded as attributes of solidity. Yet other qualities may be best considered as arising jointly from solidity and substance.

Solidity is a matter of concern to all who are interested in the contemplation, production, employment, and enjoyment of solid bodies; to scientists, manufacturers, engineers, and the public. Its assessment in terms of "blows" "bends," and kindred quantities has not been justified by results. Tests of this kind yield only casual information relating to the body tested, and such scraps of information neither constitute nor lead to knowledge of solidity. The rise of the chemical and electrical industries shows that a little knowledge is more useful—and more "practical"—than libraries of desultory information.

AUTHORS CITED

1. G. Quincke, "The Transition from the Liquid to the Solid State, and the Foam Structure of Matter," *Proc. R.S.*, 1906.
2. Ewing and Rosenhain, "Experiments in Micro-Metallurgy; Effects of Strain," *Proc. R.S.*, 1899.
3. Beilby, *Aggregation and Flow of Solids*, Macmillan, 1921.
4. Reynolds, "On the Dilatancy of Media composed of Rigid Particles in Contact," *Phil. Mag.*, 1885.
5. McConnel, "On the Plasticity of an Ice Crystal," *Proc. R.S.*, 1891.
6. Carpenter, *Single Metallic Crystals*, Iron and Steel Inst., 1923.
7. Roberts-Austen, "On certain Mechanical Properties of Metals in Relation to the Periodic Law," *Proc. R.S.*, 1888 and 1891.
   Edwards, *The Resistance of Metals to Penetration under Impac.*, Inst. of Metals, 1918.
8. Nernst (quoting Grüneisen), *Theoretical Chemistry*, Macmillan, 1923.
9. Forbes, "On the Connection between Cohesion, Elasticity, Dilation, and Temperature," *Proc. R.S. Edin.*, 1875-8.
   Allen and others, "The Mechanics of Solidity," *Nature*, 1920-1.

HYDROGEN ION CONCENTRATION AND GROWTH

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In spite of the importance of growth to the biologist, advance in our knowledge of this subject has necessarily been somewhat retarded on account of the complexity of this particular field of physiology. The changes incidental to the appearance of growing cells in plant tissues have recently, however, received a good deal of attention, and the results of the work already done tend, tentatively at least, to certain conclusions which appear to have wider applications and may well prove to be of general interest. As far as plant tissues are concerned, the subject is difficult of attack, because of the extreme impermeability of the actively growing tissues of higher plants, from which most of our knowledge is derived ; and it is almost impossible to examine their properties in the living state. In contrast to the cells of normal tissues, the dividing or meristematic cells appear to consist of dense masses of protoplasm with relatively large nuclei and few or no vacuoles. When growth is initiated in normal tissues the same type of meristematic cells appears. This appearance of growing tissues in higher plants can often be induced by wounding, and Priestley and Woffenden [34] have shown that the sequence of changes in cut potato tubers follows the liberation of fatty acids at the cut surface, which leads ultimately to the formation of an impermeable suberin layer and the blocking of the wound surface. Behind this cut surface there appears a row of dividing cells, the cork cambium, which give off to the outside rows of cork cells. The development of these non-vacuolated dividing cells from the normal vacuolated tissue appears to involve the removal of water, since it is due to the disappearance of the aqueous solution in the vacuole. It may reasonably be postulated that growth or protoplasmic synthesis resembles most other synthetic processes in plants in being a condensation of two relatively simple substances, A and B, to form a third more complex substance, C, and water. Belonging to this type of reaction are the synthesis of peptides from amino-acids, of polysaccharides from simpler sugars, and of glucosides from their constituents. The reactions are reversible and the equilibrium between the four reacting substances would be expressed by the equation:

$$\frac{(C)(H_2O)}{(A)(B)} = K \text{ (a constant)}$$

It is clear from this that the concentration of water present could be used to control the direction and equilibrium of the reaction. If the concentration of water were reduced, the concentration of C would tend to be increased, and *vice versa.* Thus, if our test-tube knowledge of chemistry can be applied to the living organism, it would seem that elimination of water from non-growing cells might well lead to an alteration in the protoplasmic equilibrium in the direction of synthesis. It must, of course, be recognised that such a synthetic process might localise in definite metabolic centres in the protoplasm, and it might then proceed even though the whole cell contained a considerable quantity of water.

An attempt has been made by Pearsall and Priestley [33] to suggest a mechanism which would allow of the removal of water under the conditions observed in growing plant tissues. In the cork cambium of potatoes, for example, the liberation of fatty acids at the cut surface causes a considerable increase in hydrogen ion concentration, and the pH value of the outer cells may fall to between pH 3 and 4. The sap reaction of the normal tissue is about pH 5·6. Similar effects are observed in other cases of cork cambium formation, and the actual dividing cells in all these cases lie on a gradient of hydrogen ion concentration, between the observed extremes. In addition, the inner cambium of flowering plants is similarly developed between the acid sap of the wood elements, usually about pH 4 to 5, and the alkaline phloem, which commonly has a reaction of pH 7 or more. Pearsall and Priestley therefore suggest that one of the essential conditions for the development of dividing cells in normal non-growing tissues is the development of a gradient of hydrogen ion concentration such that the protoplasm or its principal proteins can be reduced to an iso-electric condition. As shown by Loeb [20], this is the point at which proteins show minimum swelling, minimum osmotic pressure, maximum precipitation, and least viscosity. Since the iso-electric point of a given protein occurs at a definite hydrogen ion concentration, departures from this hydrogen ion concentration cause increased swelling, solubility, etc. It may therefore be assumed that if the protoplasm or the principal proteins in a tissue were made approximately iso-electric by an alteration in hydrogen ion concentration, then they would tend to lose water to adjacent media of higher osmotic potential, and as a result the condition in the protoplasmic or protein aggregate would favour synthesis as suggested above. Since proteins are least soluble at the iso-electric point, the formation of additional protein would be favoured at this point by the removal of the end products of the reaction, protein being least soluble and water most easily removed. The effect of precipitation of the end product of a reaction upon the rate at which the reaction proceeds is well known. It is illustrated in the case of the synthesis of protein-like substances by the Danilewsky reaction, in which " plasteins " are formed from protein degradation products by enzyme action [see Effront, 7]. Wasteneys and Borsook [43] have recently restated and confirmed the evidence for regarding this reaction as protein synthesis, and it is significant that they find the reaction to proceed most rapidly about pH 4·0, which is about the reaction at which most proteins are iso-electric.

The theoretical basis for regarding the iso-electric point as one favourable for protein synthesis in the living protoplasm appears to be fairly satisfactory, but further evidence is required as to the conditions obtaining in the growing regions of the living organism. We require to know the range of hydrogen ion concentration in which growing cells occur, and the effects of alteration of hydrogen ion concentration within this range upon the protoplasm. Further, we require to know the iso-electric points of representative proteins, and also that of the protoplasm, if different from that of its constituent proteins. So far as the two cases of growth initiation discussed above are concerned, the critical range of hydrogen ion concentration appears to lie in plants approximately between pH 4·5 and 5·5. Somewhat similar results are obtained from the consideration of the apical growing regions of plants. In stems there is a superficial layer of growing cells next to the cuticle, which is usually markedly acid, pH 3·5 to 4·5. The ground tissues are usually between pH 5 and 6. Other groups of growing cells farther inside the tissues develop around the ends of the xylem, which has usually an acid sap, pH 4 to 5. The regions of the root meristems show similar reactions, and it is noteworthy that when lateral roots develop they do so outside the xylem, with its markedly acid reaction, and not opposite the phloem, which is relatively alkaline. The evidence for the higher plants is clearly consistent with the view that the surroundings of the dividing cells have usually a reaction of about pH 4·5 to 5·0, as against the normal tissue reactions of pH 5·5 to 6·5. The impermeability of the dividing cells renders a more precise statement impossible.

The iso-electric points of a number of representative proteins are known, and there are also a few observations on micro-organisms. These are given in the following table, slightly amplified from Pearsall and Ewing [30]:

pH VALUES OF ISO-ELECTRIC POINTS

Beans and Peas	pH	*Spinach: spinacin [5]	4·0–4·6
Vicilin	3·4	Tomato: globulin	4·0
Legumin	4·4–4·6	Edestin (hemp)	5·6
*Legumelin	4·2	Yeast: cells	3·1–3·3
Wheat:		,, globulin	4·6
Glutenin	4·4–4·5	,, albumin	4·6
Gliadin	3·5–5·5	*Nitella extract	4·6–4·7
*Leucosin	4·5	Bacterium coli	3·2
*Potato: tuberin	4·4	Bacillus of rabbit septicæmia	4·2
*Carrot: globulin	4·1–4·4	B. typhosus	3·5

It will be noticed from the above table that most of the vegetable proteins have iso-electric points about pH 4·5. Particularly is this so when the proteins are present in quantity in active tissues, and hence are probably physiologically active and not merely storage forms. These "active" proteins are asterisked in the table. In the case of the alga *Nitella*, it is possible to extract from it a suspension of fragments of protoplasm, which is iso-electric in the same region about pH 4·6 to 4·7. In yeast, however, the iso-electric point of the suspended cells is about pH 3·2 (by precipitation and cataphoresis), while the principal proteins known from yeast are iso-electric at pH 4·6 [Fodor, 10; Luers and Schuster, 21]. In this case, therefore, the iso-electric point of the organism is not the same as that of its chief proteins, and it is accordingly important to determine in which region the growth optimum occurs. According to Mr. F. A. Mason, of Leeds, yeast multiplies most rapidly between pH 4·6 and 5·0, *i.e.* near the iso-electric point of the proteins present. It may be of interest to note also that according to Rona and Grassheim [37] yeast respires most rapidly between sharp limits of pH 4·5 and 6·6.

So far as the higher plants are concerned, the relation between the iso-electric points of the chief proteins and that of the protoplasm remains unknown. Indications, however, exist which suggest that the two types of iso-electric points occur at similar hydrogen ion concentrations. From the effects of salts in acid and alkaline solutions, Endler [8] concluded that the iso-electric point of *Elodea* protoplasm was in the region pH 3·8 to 4·1. From the swelling curves of potato tissue, Robbins [36] assumes a point of minimum swelling between pH 5·5 and 6·0, and he regards this as the iso-electric point of potato. There are, however, a number of swelling minima in such tissues at different pH values, and as Robbins only worked with a limited pH range his results do not settle the question. There is, in fact, a point of minimum swelling in potato about pH 4·5 [31], and in view of the fact that about 85 per cent. of the nitrogen in potato is extracted as tuberin, which has an iso-electric point at pH 4·4, there is no reason, at present, to assume any other iso-electric point for potato protoplasm. The difficulty of obtaining protoplasm from the higher plants makes it necessary to consider indirect methods of tackling the problem. The protoplasm of most normal plant tissues behaves as an anion, that as though it were an ampholyte on the alkaline side of its iso-electric point. It therefore stains most readily with basic dyes, *i.e.* dyes in which the dye is a colour base. Between pH 3 and 4, however, it stains more readily with acid dyes, *i.e.* salts of a colour acid, and therefore under these conditions it reacts as a base [31] and as though it were on the acid side of its iso-electric point. This statement appears to be correct for potato (see also Robbins, *loc. cit.*), beans, and wheat, the proteins of which have also been examined (see Table). Heat coagulation of protoplasm is produced most rapidly in slightly acid solutions, mostly slowly in slightly alkaline solutions [Lepeschkin, 18, 19]. In this it resembles in a very striking manner the vegetable albumins, like *leucosin*, and in these heat coagulation takes place most rapidly at the iso-electric point. Addoms [1] has examined the effect of acid solutions upon the protoplasm of wheat root-hairs under dark-ground illumination. It was found that solutions more acid than pH 4·0 caused the protoplasm to become markedly more granular, while the granules tended to coalesce. The observed facts suggest the precipitation of proteins at or below the iso-electric point, and this explanation appears to be the more probable as leucosin, the physiologically active protein of wheat, has an iso-electric point at pH 4·5. It is probable that any solution of higher ion concentration than the iso-electric point would produce this change under the conditions of the experiment, as the solution could not enter instantaneously, and would therefore only gradually change the reaction of the protoplasm, causing gradual precipitation of the proteins. If, as in this case, precipitation is produced in protoplasm in the vicinity of pH 4 to 4·5, it ought to occur, to some extent at least, in meristematic tissues, if these are approximately iso-electric. The observation of Tupper-Carey and Priestley [41], that protein occurs in the walls of plant dividing cells, is, therefore, very significant, especially as this protein tends to disappear (? to be redissolved) as the cells differentiate.

Permeability effects give similar indications. In potato and carrot, the permeability of the protoplasm to chlorine ions markedly increases at or below the pH value at which the chief proteins are iso-electric [31]. In *Nitella*, this change in permeability, noted by Hoagland and Davis [14], coincides with the iso-electric point of the protoplasm [31]. The available evidence therefore suggests that in most cases the iso-electric points of the protoplasm is similar to that of the proteins extracted and lies between pH 4 and 5. The proteins in the protoplasm are therefore normally on the alkaline side of this region, since the plant sap has usually a higher pH value. They would thus behave as anions to dyes, and they would migrate to the anode under the influence of an electric current. Meier [23] has shown this to be the case with the living roots of Canadian field pea. Particles in the protoplasm moved to the anode. It is of interest to note that this movement was only observed in non-growing tissues, not in the dividing cells. This suggests that the growing tissues are approximately iso-electric. It is not possible at present to attach too much significance to this interpretation, as, in view of the apparently dense nature of the protoplasm in the dividing cells, particles may not be free to move under the forces applied.

The available evidence derived from plant tissues has been treated at some length above, because the problem is not easily tackled experimentally. The growth of a plant involves not merely cell division, but also the subsequent extension and elongation of the cells, processes which are obviously favoured by different factors. Pursuing the analogy with proteins, the farther the hydrogen ion concentration is from the iso-electric point, the more rapid water absorption and extension will be. This two-fold nature of growth is very clearly demonstrated by Freund [12] for the alga *Œdogonium*. In food solutions of varying concentrations, insufficient supplies of food material may retard mitosis, while higher concentrations favour mitosis but stop or hinder cell extension—presumably because the cells are unable to absorb water from the osmotically concentrated solutions.

Growth must also be dependent not only upon the actual synthesis of protoplasm, but also upon the other metabolic activities of the tissues. Unless these can proceed rapidly the growth of the whole plant may be limited. F. F. Blackman's reference to growth as the " finished product of the metabolic loom " is a singularly happy expression of this fact. Strictly speaking, therefore, an attempt to relate growth to hydrogen ion concentration should also consider the effect of this factor upon other metabolic activities, an unprofitable proceeding in the present state of our knowledge. There is, however, a little evidence showing the effect of hydrogen ion concentration upon the activity of some typical plant enzymes. It is probably also safe to say that if in normal tissue the proteins behave as anions, then normal metabolism is unlikely if the acidity of the tissue is increased to a higher value than that of the protein iso-electric points. Such treatment is known to alter the proportions and quantities of different ions which may be absorbed, and hence it will indirectly affect growth. Since it also leads to death of the tissue [31] by protoplasmic precipitation, it might be anticipated that growth will proceed most rapidly slightly on the alkaline side of the iso-electric point. It is found in practice that the lower pH limit of growth is quite close to the iso-electric point of constituent proteins. Thus in wheat, retardation of root growth occurs in culture solutions of pH 4·1, according to Salter and McMvaine [38]. Weis [45] finds that wheat (and barley) only grow well in culture solutions if the pH value exceeds 4·5. Bakke and Erdmann's results [3] show that no good growth of wheat is experienced if the culture is below pH 4·3. The effect of higher hydrogen ion concentrations on the protoplasm of the same variety of wheat has already been considered [Addoms, 1]. With broad beans a similar result has been obtained in this laboratory. Root growth is markedly reduced at or below pH 4·2, *i.e.* just below the iso-electric point of two of the chief bean proteins. Reference has already been made to the simpler case of yeast cells.

In regard to the relation of hydrogen ion concentration to enzyme action, the limited data available is very suggestive. The optimum for the proteolytic activity of papain occurs between pH 4 and 5 [Frankel, 11]. Malt protease is most active at pH 4·6 [McClendon, 24], and malt peptase at pH 3·7 to 4·3 [Lundin, 22]. The sucrolytic action of bananas is most rapid about pH 4 to 4·5 [Falk and McGuire, 9], while bean dehydrogenases show optimum activity between pH 4 and 5 [Lehmann, 17]. The oxidases, however, are most active in alkaline media [*e.g.* Raper and Wormall, 35], while the amylases are, as a rule, most effective about pH 5 to 5·4 [Siöberg, 40]. On the other hand, the two latter types of enzyme do not apparently play an important part in the plant-growing points. It is interesting to note that proteases, sucrase, and dehydrogenase may show maximum activity at reactions akin to those of the growing points. One remaining line of advance is possibly worthy of mention. Rapidly growing tissues are often distinctly more acid than the mature or non-growing organs. Two examples indicate the sort of evidence available. Atkins [2] states that unripe bananas have a hydrogen ion concentration of pH 4·6 to 4·8, while ripe (*i.e.* non-growing) fruits are at pH 5·6 to 6·0. The reverse may occur in dormant seeds. Pack [29] finds that during the period of after-ripening in juniper seeds, the pH value of embryo falls from between pH 8·8 and 8·4 to pH 4·4 to 6·0. in ninety days. The embryo will grow only under the latter conditions. It is of interest to note that the water content of the embryo decreases slightly during this change in hydrogen ion concentration, and both facts assume greater significance in view of the previous evidence which has been considered.

Weber [44] has recently reviewed the subject of growth initiation at some length, and while he accepts the hypothesis of Pearsall and Priestley, he prefers to state it in a broader manner, *viz.* that cell division is associated with alterations in colloidal state of the protoplasm and that alterations of hydrogen ion concentration affect colloidal state. This wider statement is, in the present state of our knowledge, probably more judicious. Thus, to take a single example, many plant tissues show several points of minimum swelling at various hydrogen ion concentrations, in addition to that at the iso-electric point [31]. Weber points out that there is much evidence relating the viscosity of protoplasm to various growth factors and to external conditions. In Haberlandt's experiments on restarting cell division in *Pelargonium* epidermis, the cells in the dividing state have rounded nuclei, though otherwise the nuclei are spindle shaped. Both Schwarz (1892) and Nemec [28] have suggested that embryonal cells have rounded nuclei because they are more liquid and therefore offer less resistance to surface tension. Kühne pointed out that amœboid cells round off prior to cell division, and that nuclear and cell division is associated with relative changes of volume and of water content of the different cell components. Chambers [4] and Kite [16] analyse the viscosity changes in sea urchin eggs. Changes of colloidal state are, therefore, quite characteristic of developing embryonal cells. There is, moreover, some evidence that the factors affecting viscosity will also affect cell division. Thus Heilbrunn [13] found that the concentrations of narcotics affecting cell division were the same as those affecting viscosity. The effects of hydrogen ion concentration do not appear to be carefully worked out as yet, although they may perhaps be inferred from the known effects of carbon dioxide. This substance is apparently produced at varying rates during mitoses, and most rapidly when the cytoplasm divides. Jacobs [15] was able to show that in Paramœcia, colpidia, and Arbacia eggs (as in Spirogyra cells) short exposures to CO_2 decrease the protoplasmic viscosity and longer exposures then increase it. While both changes are reversible at first, prolonged exposures lead to irreversible coagulation. McClendon and Mitchell [26] found that artificial parthenogenesis could be induced in sea urchin eggs by exposure to CO_2 for short periods. There was increased permeability on the formation of the membrane [McClendon, 25]. Moore [27] has pointed out that cytolysis in sea urchin eggs is associated with increased fluidity (*i.e.* decreased viscosity) and increased permeability. Now in trout eggs, according to Scheminsky [39], the egg ampholytes are anionic. If sea urchin eggs are similar in this respect, all the phenomena mentioned above might be associated with the changes in colloidal state following approach to the iso-electric condition. The effective action of CO_2 might be due to the changes in hydrogen ion concentration. It is of great interest to notice that the most effective method of producing artificial parthenogenesis resembles that mentioned above in the use of an acid medium. Loeb exposed sea urchin eggs for a varying time to treatment with 2·8 c.c. of 0·1 M butyric acid in 50 c.c. of sea-water. The eggs were subsequently transferred to hypertonic sea-water. It may be suggested that the physiological effects of this treatment in starting growth are as follows: (1) The formation of a membrane as suggested by Loeb, (2) bringing the protoplasm or its constituent proteins near to the iso-electric point or to a point of minimum swelling, (3) withdrawal of water by means of the hypertonic solution. The effect of butyric acid would then fall in line with that produced by carbon dioxide. It is, of course, probable that other factors might produce similar effects, and it is by no means certain that CO_2 is effective only through its effect on hydrogen ion concentration. According to Clowes and Smith [6] CO_2 is much more effective in altering the rate of cell division than mineral acids, and this effect is not related to the hydrogen ion concentration. They suggest that CO_2 is more soluble than mineral acids in organic compounds, and hence is relatively more effective. They find that hydrochloric acid has little effect on cell division between pH 5 and 8, but retards it markedly below pH 4·6. Similar results are obtained by Vles, Dragon, and Rose [42], who also note that when growth ceases the protoplasm becomes granular. While the data as a whole do not permit of any final conclusion, they are of great interest when compared with those for plants, and suggest that this question would repay further examination. The whole field which has been briefly surveyed in this paper is one of the most interesting with which the modern biologist is confronted.

REFERENCES

1. ADDOMS, *Amer. Jour. Bot.*, **10**, 1922, 211.
2. ATKINS, *Sci, Proc. Roy. Dublin Soc.*, **16**, 1922, 414.
3 BAKKE and ERDMANN, *Amer. Jour. Bot.*, **10**, 1922, 18.
4. CHAMBERS, *Jour. Gen. Physiol.*, **2**, 1919, 49.
5. CHIBNALL, *Jour. Biol. Chem.*, **61**, 1924, 303.

6. Clowes and Smith, *Amer. Jour. Physiol.*, **64**, 1923, 144; and *Jour. Biol. Chem.*, **50**, 1922, iv.
7. Effront, *Biochemical Catalysts in Life and Industry*, New York, 1917.
8. Endler, *Biochem. Zeitschr.*, **45**, 1912, 359.
9. Falk and McGuire, *Jour. Gen. Physiol.*, **3**, 1921, 595.
10. Fodor, *Kolloid Z.*, **27**, 1920. 58.
11. Frankel, *J. Biol. Chem.*, **31**, 1917, 201.
12. Freund, *Ber. Deutsch. Bot. Ges.*, 1923.
13. Heilbrunn, *Amer. Jour. Physiol.*, **64**, 1923.
14. Hoagland and Davis, *Jour. Gen. Physiol.*, **5**, 1923, 629.
15. Jacobs, *Biol. Bull.*, **42**, 1921, 1.
16. Kite, *Amer. Jour. Physiol.*, **32**, 1913, 146.
17. Lehmann, *Bot. Notiser*, 1922, 289.
18. Lepeschkin, *Ber. Deutsch, Bot. Ges.*, **28**, 1910, 91 and 383.
19. Lepeschkin, *Ibid.*, **29**, 1911, 247 and 349.
20. Loeb, *Proteins and the Theory of Colloidal Behaviour*, New York, 1922.
21. Luers and Schuster, *Kolloid Zeit.*, **32**, 1923, 334.
22. Lundin, *Biochem. Z.*, **121**, 1923, 193.
23. Meier, *Bot. Gaz.*, **72**, 1921, 113.
24. McClendon, *Physical Chemistry of Vital Phenomena*, Princeton, 1917.
25. McClendon, *Amer. Jour. Physiol.*, **27**, 1910, 240.
26. McClendon and Mitchell, *Jour. Biol. Chem.*, **10**, 1911–12, 459.
27. Moore, *Jour. Biol. Chem.*, **28**, 1916–17, 475.
28. Nemec, *Bot. Centralbl.*, **77**, 1889, 1.
29. Pack, *Bot. Gaz.*, **71**, 1921, 32.
30. Pearsall and Ewing, *Biochem. Jour.*, **18**, 1924, 329.
31. Pearsall and Ewing, *Jour. Exper. Biol.*, **2**, 1925, 347.
32. Pearsall and Ewing, *New Phyt.*, **23**, 1924, 193.
33. Pearsall and Priestley, *New Phyt.*, **22**, 1923, 185.
34. Priestley and Woffenden, *New Phyt.*, **21**, 1922, 252.
35. Raper and Wormall, *Biochem. Jour.*, **17**, 1923.
36. Robbins, *Amer. Jour. Bot.*, **10**, 1922, 412.
37. Rona and Grassheim, *Biochem. Z.*, **134**, 1922, 146.
38. Salter and McMvaine, *Jour. Agric. Res.*, **19**, 1920, 73.
39. Scheminsky, *Biochem. Z.*, **132**, 1922, 154.
40. Sjöberg, *Biochem. Z.*, **133**, 1922, 218.
41. Tupper-Carey and Priestley, *Proc. Roy. Soc.*, **95**, 1923, 109.
42. Vles, Dragon, and Rose, *Compt. Rend.*, **176**, 1923, 133.
43. Wasteneys and Borsook, *Jour. Biol. Chem.*, **62**, 1924, 15.
44. Weber, *Naturwissensch.*, **16**, 1924, 1.
45. Weis, *Medd. Plantefysiol. Lab.*, 1919, 239.

THE MAGNIFICATION OF ACOUSTIC VIBRATIONS BY SINGLE AND DOUBLE RESONANCE

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The problems which engage the attentions of investigators in acoustics may generally be placed under one or other of three headings, according as they refer to the production, transmission, or reception of sound. The first of the groups so formed is concerned with the mechanism of sound-sources, the second with the transmission of sound-waves through the atmosphere and other media, while the third has reference to the means by which we are able to detect and record sound-waves and to measure their amplitudes and wave-lengths. It is with one of the problems of the third group, relating to the employment of resonance with certain types of sound-receiving apparatus, that it is proposed to deal in the present article.

Existing sound-receiving instruments may be divided into two classes according as they are intended for the reproduction or recording of speech and musical compositions, or for purely scientific purposes such as the measurement (or comparison) of the amplitudes of sound-waves. Examples of the first class are the microphones used in telephony and " wireless," and the apparatus employed in the manufacture of gramophone records. In this class, also, we have instruments intended for the examination of wave-form, such as the phonodeik of D. C. Miller [1].[1] One of the principal requirements of such instruments is that they shall be capable of giving a uniform response over a wide range of frequencies. Resonance is to be avoided, for its existence implies that some sounds will be recorded more vigorously than others, so that the reproduced sound (or wave-form) will not have the same character as the original, and may, in fact, be very different. As the removal of all traces of resonance is generally impossible, it is usual to attempt to overcome this difficulty by making the resonance frequencies of the instruments either much higher or much lower than any that are likely to occur in the received sound.

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[1] The numbers in brackets refer to the notes and references at the end of the article.

In instruments of the second class, on the contrary, tuning, or resonance, is generally an advantage. One reason for this is that, in experiments involving the measurement of sound-amplitudes, it is usually desired to concentrate attention on some particular wave-length, and the most convenient way of doing this is by employing a receiving instrument tuned to the frequency of the tone on which observations are to be made. A tuned instrument, moreover, has the advantage that it is less susceptible to disturbances by stray sounds—an important consideration when it is remembered that many acoustical experiments are necessarily conducted in the open air or in buildings the walls of which provide but an indifferent protection against unwanted noises.

The special advantage, however, of tuned reception lies in the very large " magnifications " which are obtainable by the employment of resonance. One of the principal difficulties in the way of making accurate quantitative measurements of acoustic phenomena is due to the minuteness of the motions and pressure-variations occurring in sound-waves, but the magnification of these by means of a resonator renders it possible to construct instruments in which the effects to be observed are comparatively large and easily measurable. The type of instrument here contemplated consists of two essential parts—a tuning device or resonator, and a sound-detecting device or detector. It is the function of the resonator to select sounds of a particular wave-length and to magnify the motions or pressure-variations to such an extent that they may be easily recorded by the detector. The last named is exposed to the magnified acoustical effects and translates them into terms of some easily observed quantity, such as the deflection of a light moving part, a change in ohmic resistance, and so on. Typical detectors are the hot-wire microphone grid and the Rayleigh disc. In the former it is a change in ohmic resistance which is observed, while in the latter it is the rotation of a small circular mirror suspended by a fine quartz fibre.

It is evident that the magnification of acoustic vibrations (whether motions of the air particles or pressure-variations) obtainable by the use of a resonator is an important element in determining the effectiveness of tuned receiving instruments. We will therefore consider the principal factors affecting magnification in some well-known instruments, beginning, as an introduction, with the simple case of the resonator as used aurally by Helmholtz in his classical work on the quality of musical notes.

The type of resonator used by Helmholtz—generally known as the " Helmholtz resonator "—consists of a spherical or cylindrical vessel (the exact shape does not matter) in which there is a single orifice providing communication between the interior of the vessel and the outside air. One of the forms used by Helmholtz—spherical in shape and having an orifice with a short neck—is shown diagrammatically in Fig. 1. The air in such a vessel has a natural frequency of its own, and the natural tone is easily elicited by tapping the sides of the vessel or blowing across the edge of the orifice. When the resonator is exposed to sound-waves having the same frequency as that of its own natural tone, the air in the orifice is set into sympathetic vibration, and moves with an amplitude which is many times greater than that of the original sound-wave. Similarly, the fluctuations in pressure inside the resonator, corresponding with the movements of the air in the orifice, are many times greater than those in the sound-wave, so that if the ear is placed in communication with the interior of the vessel, the particular tone to which the resonator responds is heard with increased loudness. It was in this way that Helmholtz used the resonator, the communications with the ear being by way of a small nipple shown at N, Fig. 1. The resonator, together with the ear applied to the nipple, constitutes a tuned receiving instrument in which the ear plays the part of the detector.

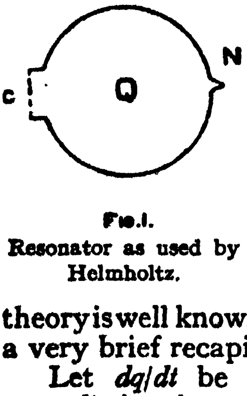

Fig. 1.
Resonator as used by Helmholtz.

In order to form some estimate of the assistance which such a device gives to the ear, it is necessary to refer to the simple theory of the Helmholtz resonator. This theory is well known and is given in most textbooks on Sound, and a very brief recapitulation will suffice for our present purpose.

Let dq/dt be the instantaneous current of air (c.c. per second) in the orifice—directed inwards—and let L be the length of the neck. Then the rate of change of momentum in the orifice is $\frac{d}{dt}\left(\rho L \frac{dq}{dt}\right)$, ρ being the density of air. In order to obtain the equation of motion, this quantity must be equated to the force acting on the air in the orifice due to the rise of pressure dp inside the resonator caused by the introduction of the extra volume of air q. If σ represents the cross-sectional area of the neck, this force is $-\sigma.dp$. The changes of pressure corresponding with the movements of the air in the orifice are assumed to take place adiabatically, and accordingly $dp = a^2 d\rho = a^2\rho(q/Q)$, where a is the velocity of sound in air and Q is the internal volume of the resonator. The equation of motion of the air in the orifice is thus:

$$\frac{d^2q}{dt^2} + \frac{a^2}{Q}\left(\frac{\sigma}{L}\right)q = 0 \qquad \ldots\ldots\ldots \quad (1)$$

Actually, the motion of the air is not confined entirely to the orifice, but extends for a little way both inside and outside the resonator. The momentum of the moving air as given above is therefore underestimated, but a correction on this account can be made by adding to the length L, another length a, called the "end-correction." For a cylindrical orifice of radius R, Rayleigh has shown that the end-correction (for each end) is 0·8 R if there is a flange, and 0·6 R if there is no flange. Generally one end is flanged and the other unflanged, so that the total correction is 1·4 R. Let L^1 be the corrected value of L, then the linear quantity (σ/L^1) is constant for a given orifice. It is called the "conductance" of the orifice and is usually denoted by c and expressed in centimetres. Substituting c for (σ/L) in equation (1), we see that the frequency of the resonator is given by:

$$n = \frac{a}{2\pi}\sqrt{\frac{c}{Q}} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

which is the formula given by Rayleigh. Frequencies calculated from (2) are found to agree very satisfactorily with experimental values. In order to determine the motion of the air in the orifice due to a sound-wave of given pressure-amplitude, say F, allowance must be made for the dissipation of sound-energy from the resonator. This may arise from two causes: (1) From the escape of sound-energy by way of the orifice into the surrounding air, and (2) from the operation of viscous forces in the orifice giving rise to the degradation of sound-energy into heat. The first of these is analogous to the escape of energy by radiation from an electrical oscillating circuit, while the second is analogous to the losses due to the ohmic resistance of the circuit. Allowance for the losses from both causes can be made in the equation of motion by the insertion of a term proportional to the current in the orifice, and the final equation from which we can determine the forced vibration due to a pressure-variation F cos wt at the mouth is [2]:

$$\frac{d^2q}{dt^2} + 2h\frac{dq}{dt} + w_0^2 q = \frac{cF}{\rho}\cos\ wt \quad . \; . \; . \; . \; . \; . \; . \quad (3)$$

where w_0 is written for 2π × the natural frequency of the resonator, that is, for $a\sqrt{c/Q}$. The forced vibration is thus:

$$q = \frac{cF/\rho}{\sqrt{\{(w^2 - w_0^2)^2 + 4w^2h^2\}}}\ \text{o s}\ (wt - \theta) \quad . \; . \; . \; . \; . \quad (4)$$

It may be assumed that the resonator is exactly tuned to the frequency of the sound which it is desired to hear, so that $w = w_0$, and the amplitude of q as given by equation (4) is then simply $cF/2\rho w_0 h$.

The loudness of the sound heard by the ear depends on the amplitude of the pressure-variation occurring in the resonator. In order to obtain some idea of the advantage to be gained by the use of the resonator, we will define the "pressure-magnification" as the ratio of the maximum pressure-variation inside the resonator to the maximum pressure-variation in the incident sound-wave. Since $dp = a^2\rho(q/Q)$, it follows that the maximum pressure-change inside the resonator is $\frac{a^2\rho}{Q}\cdot\frac{cF}{2\rho w_0 h}$, or $\frac{w_0 F}{2h}$. The pressure-magnification is the ratio of this quantity to F, that is, $\frac{w_0}{2h}$, or $\frac{\pi n_0}{h}$, where n_0 is the number of vibrations per second in the resonant tone. It is thus proportional to the frequency of the resonator and inversely proportional to the damping factor.

It may be noted here that there is another kind of magnification shown by resonators, namely, the velocity-magnification, to which we shall have occasion to refer later. As it is important to distinguish between the two kinds of magnification, we will denote the pressure-magnification by M_p and the velocity-magnification by M_v. Thus $M_p = \frac{\pi n_0}{h}$.

To find a numerical value for M_p in any particular case it is necessary to discover the value of h. It has previously been mentioned that the magnitude of h is dependent on two factors, namely, the rate at which sound escapes from the resonator by radiation, and the rate at which it is converted into heat by the operation of viscous forces in the orifice. In the case of resonators with wide mouths the losses due to viscosity are small compared with those due to radiation, and in these circumstances the value of h may be calculated by means of a well-known formula, viz. $h = (\pi n_0^2 c/2a)$ seconds^{-1} [3], the modulus of decay being the reciprocal of this quantity, *i.e.* $2a/\pi n_0^2 c$ seconds. Substituting this value of h in the expression for M_p we obtain $2a/n_0 c$, by means of which we can calculate how many times the pressure-variation inside the resonator is greater than the pressure-variation in the original sound-wave.

As an example, consider the case of a resonator tuned to respond to a tone of 256 vibrations per second, and having a short-necked circular orifice of 3 cm. in diameter. The conductance of such an orifice is approximately equal to its diameter [4]. The pressure-magnification is therefore $\frac{2a}{n_0 c} = 88$. This shows how great an increase in sensitiveness to a particular tone can be obtained with the help of such a simple piece of apparatus as a Helmholtz resonator. In practice there will inevitably be some loss of acoustical energy in the communication of the pressure-changes to the ear through the nipple (N, Fig. 1), so that an estimate of the increase in sensitiveness based on the above figure would err somewhat on the side of being too great.

The above expression for the pressure-magnification gives some indication of the lines along which we should proceed in order to discover the best dimensions for the construction of a resonator of given frequency. If n_0 is fixed, the value of M_p increases as c is made smaller, but it must be remembered that in obtaining the expression for M_p allowance was made only for the radiation losses from the resonator. If c is diminished by reducing the size of the orifice, a point is soon reached at which (as will be seen later) viscosity losses must also be taken into account. There is, in fact, a limit to the extent to which the orifice may be reduced, the advantage gained by any further diminution in the value of c being outweighed by the increase in damping due to viscosity. Hence, for every frequency, there exists an optimum value of c which, if employed for the construction of a resonator, will give the maximum value to the pressure-magnification. In the present imperfect state of our knowledge regarding the viscosity losses in orifices of various shapes and sizes, however, it is not possible to give any precise information concerning these optimum values of c.

A modern application of the Helmholtz resonator to sound-reception is to be found in the selective hot-wire microphone. The resonator as used aurally after the manner of Helmholtz is a qualitative instrument, useful only for identifying and establishing the existence of tones which would otherwise be faint or inaudible to the unaided ear. In order to obtain quantitative observations it is necessary to replace the ear by a detector, the response of which is some function of the amplitude of the vibration induced in the resonator. This is, in effect, what is done in the hot-wire microphone invented by Major W. S. Tucker [5]. In this instrument a short length of fine platinum wire, 6 μ in diameter, is mounted in the orifice of a resonator. The wire is arranged in the form of three loops attached to a small porcelain bridge, the arrangement being known technically as a "grid." The grid is heated to just below red heat by means of an electric current of about 25 milliamperes, and when hot has a resistance of 200 to 300 ohms. When the microphone is exposed to sound-waves in tune with the resonator, the vibratory motion of the air in the orifice cools the grid and there is a consequent drop in its ohmic resistance. This can be measured by one of the usual standard methods (say, by a Wheatstone bridge), and provides a ready means of estimating the strength of the sound affecting the microphone.

It will be seen that there is an essential difference between the way in which the resonator was used by Helmholtz and the way in which it is used in the hot-wire microphone. In the former case it was employed to obtain enhanced pressure-variations, which were then transmitted to the ear by way of the nipple. In the latter case the resonator is used to obtain increased movements of the air particles, which movements are recorded by the hot-wire grid. As will be seen later, it is the velocity-magnification (M_v) which is the important factor in determining the sensitiveness of hot-wire instruments.

The resonators used in the construction of hot-wire microphones are usually cylindrical in shape and have the form shown in section in Fig. 2. The orifice (*c*) in which the heated grid (M) is mounted is also cylindrical, and on account of the necessity for shielding the grid from accidental currents of air it is usually made to quite small dimensions, a common size being 10 mm. long and 5 mm. internal diameter. The instrument is made in brass with ebonite insulation where necessary, and tuning is accomplished by adjusting the internal volume Q of the cylindrical body of the microphone.

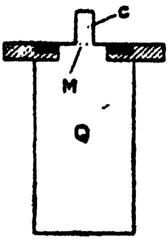

Fig. 2. Form of Helmholtz resonator used in hot-wire microphone.

In order to understand fully the working of this type of microphone it would be necessary to establish two relations, one connecting the pressure-amplitude in the sound-wave with the amplitude of the vibration in the orifice, and another connecting the amplitude in the orifice with the ohmic change in the grid. If both these relations were known it would be possible to employ the hot-wire microphone for measuring the amplitude of sound-waves in C.G.S. units. The first part of the problem concerns the performance of the resonator and can be solved by means of the equations already given; but the second part of the problem, relating to the behaviour of the grid, still awaits a complete and satisfactory solution. It is known, however, that for small amplitudes at a given frequency the ohmic change in the grid is proportional to the square of the maximum velocity in the orifice [6], while for larger amplitudes experiments by R. C. Richards [7] indicate that the ohmic change is a function of the maximum velocity only and is independent of the frequency. We see, therefore, that in examining the performance of the resonator in relation to the sensitiveness of the instrument, it is the velocity-magnification (M_v) to which attention must be directed. This velocity-magnification may be defined as the ratio of the maximum velocity occurring in the orifice of the resonator to the maximum (particle) velocity in a *plane* wave which is stimulating the microphone [8]. It is necessary to specify the kind of wave because it is the pressure-amplitude in the wave which determines the motion in the orifice, and the relation between pressure-amplitude and particle-velocity is dependent on the shape of the wave fronts.

The maximum velocity in the orifice of the resonator is $\frac{1}{\sigma}\left|\frac{dq}{dt}\right|$, and, considering only the case of exact tuning ($w = w_0$), we see from equation (4) that $\frac{1}{\sigma}\left|\frac{dq}{dt}\right| = \frac{cF}{2ph\sigma}$. The theory of plane waves of sound shows that the maximum particle-velocity associated with a pressure-amplitude F is F/ap. The velocity-magnification obtainable from the resonator is therefore $M_v = \left(\frac{cF}{2ph\sigma}\right)\Big/\left(\frac{F}{ap}\right) = \frac{ac}{2h\sigma}$. This expression is, of course, applicable not only to hot-wire microphones, but to other instruments in which a detector is placed in the orifice of a resonator. Such an instrument, for example, is the late Prof. A. G. Webster's "phonometer" [9], in which a very light disc carrying a small mirror is mounted in the orifice. The disc is set in forced vibration by the oscillatory air-currents, and the amplitude of its motion is observed by means of a beam of light reflected from the mirror, after the manner of a vibration-galvanometer.

Comparing the value of M_p with that of M_v, we see that $\frac{M_p}{M_v} = \frac{2\pi n_0 \sigma}{ac} = \frac{2\pi\sigma}{\lambda c}$, λ being the wave-length of the sound. Since the conductance c is equal to σ/L^1, it follows that, for any particular resonator, the pressure-magnification is to the velocity-magnification in the proportion $2\pi L^1/\lambda$. Now, all the dimensions of a Helmholtz resonator are small compared with the wave-length of the natural tone, so that L^1/λ is a very small fraction (generally between ·01 and ·05), and hence it follows that, for the same resonator, M_p is very much less than M_v.

It is found by experiment that the values of the damping factor h for the rather narrow orifices used in the construction of hot-wire microphones are very much greater than would be required to account for radiation losses alone. To illustrate this point the case may be quoted of a resonator which responded to a tone of 256 vibrations per second, and which had a cylindrical orifice 10 mm. long and 4·5 mm. in diameter. The damping factor of this resonator, determined experimentally by a method which need not be described here, was found to be 49 seconds^{-1}, whereas the damping factor calculated from the radiation formula $\left(h = \frac{\pi n_0^2 c}{2a}\right)$ is only 0·7 seconds^{-1}. Thus in the case of so small an orifice, the radiation losses are almost negligible, and practically the whole of the damping must be attributed to the effects of viscosity.

The expression for M_v given above indicates that the magnification of velocities obtainable by the use of a resonator can be increased by reducing the cross-sectional area σ of the orifice. This reduction in cross-section, however, is accompanied by a rise in the damping factor owing to the greater effects of viscosity. Hence, as in the case of pressure-magnification, there is a limit beyond which it is no longer advantageous to reduce the size of the orifice. In spite of the adverse effects of viscosity the magnifications obtainable from resonators with quite small orifices are nevertheless surprisingly large. Thus, in the case of the resonator mentioned previously with a frequency of 256 vibrations per second, we have $\sigma = \frac{\pi(0{\cdot}45)^2}{4}$ cm.^{2}, and $h = 49$ sec.$^{-1}$. The value of the conductance c calculated from equation (2) by inserting the appropriate values of n_0 and Q, was 0·115 cm., so that putting $a = 33{,}760$ cm. per second, we find that $M_v = \frac{ac}{2h\sigma} = 249$. That is, the motions in the sound-wave are magnified nearly two hundred and fifty times in the orifice of the resonator.

Although this result shows that the velocity-magnifications obtainable by the use of Helmholtz resonators are very great, it is found in practice that the sensitiveness of singly resonated instruments is insufficient for the requirements of some quite ordinary experiments. In order to procure still greater sensitiveness, tuned microphones are made with double instead of single resonators. This application of double resonance to sound-receiving instruments for the purpose of enhancing sensitiveness is due to Prof. C. V. Boys, who used the principle many years ago for making a very delicate Rayleigh disc instrument now known as the "Tonomicrometer" [10].

A simple form of double resonator, called the Helmholtz double resonator, is shown in Fig. 3. It can be used with either Rayleigh disc or hot-wire grid, and consists of two Helmholtz resonators in series. The sound enters through the orifice c_1 of the large outer resonator Q_1. The small inner resonator Q_2 communicates with the interior of the outer resonator through the narrow orifice c_2. It is in this orifice that the detector (Rayleigh disc or hot-wire grid) is placed.

Very little experience with singly and doubly resonated instruments is sufficient to show that the use of a properly tuned double resonator in place of a single one is accompanied by a very marked increase in sensitiveness. The construction of a double resonator which will be very sensitive at a particular frequency is, however, by no means a simple matter. Suppose, for example, that we have a small resonator tuned to a frequency n_0 and that it is desired to enhance its sensitiveness by the use of double resonance. If we combine this small resonator with another larger one, also tuned to n_0, in the manner shown in Fig. 3, it will not in general be found that the sensitiveness at n_0 is greatly increased, although this may happen in special cases. It will, however, be found that the instrument is very sensitive at *two* frequencies, one of which is greater and the other less than n_0. The two resonators, in fact, when combined together, react one on the other, forming a coupled system with two degrees of freedom, and exhibiting the characteristics usually associated with such systems. The extent to which the two affect each other is determined by the relative size of the orifices c_1 and c_2. If these are of comparable dimensions, the reaction between the two resonators will be great, for it is obvious that the presence of the inner resonator will then have considerable affect on the pressure-changes in the outer one. The coupling in this case is "tight." If, on the other hand, the inner orifice is very small compared with the outer one, the presence of the inner resonator has but little effect on the pressure-changes in the outer one, and the coupling is said to be "loose."

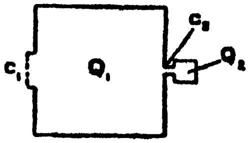

FIG. 3.
Helmholtz double resonator.

The case of extremely loose coupling, when the reaction between the component resonators may be neglected, is susceptible to easy theoretical treatment, and the result, although of limited application, is of some interest as it illustrates the idea underlying the use of double resonance for the purpose of obtaining increased magnification. Suppose, then, that the inner orifice is so small that the motions and pressure-changes in the outer resonator may be regarded as approximately unaffected by the presence of the inner one. If both the component resonators are tuned to the same frequency the sound may be supposed to be magnified first of all by the outer resonator and then again by the inner one. The magnification due to the outer resonator is that of the *pressure*-variations in the incident wave, the magnified pressures being produced inside the outer resonator and thence operating on the inner one where the second magnification takes place. Thus, let M_p[1] be the pressure-magnification ordinarily associated with the outer resonator, so that if F is the pressure-amplitude in the incident wave, the magnified pressure-amplitude inside Q_1 will be $M_p^{I} . F$. If the orifice c_2 is a narrow one, as is supposed to be the case, the radiation losses from it may be disregarded, since they will be small compared with the viscosity losses. Hence the pressure-variation in Q_1 will produce an oscillation in the orifice c_2 which will have approximately the same amplitude as if the inner resonator alone were exposed to a plane sound-wave of pressure-amplitude $M_p^{I} . F$. Let M_v^{II} be the velocity-magnification belonging to the inner resonator, then we see that the overall velocity-magnification due to the double resonator is the product $M_p^{I} . M_v^{II}$, and the advantage of the double over the single resonator is expressed by the factor M_p^{I}.

If the above theory were strictly applicable to resonators used in practice, the magnifications obtainable would be very large indeed, since the fullest use would be made of the magnifying powers of both components. It cannot, however, be used for any but extreme cases of loose coupling, and then only as a means of obtaining an approximation which should be regarded as an upper limit to the magnification.

In general, account must be taken of the reaction between the resonators, and for this purpose it is necessary to develop a more complete theory, the principal results of which may be briefly stated. In common with all coupled systems of this kind, the double resonator exhibits two resonance frequencies, one of which is always higher and the other lower, than the frequency of either component. By an extension of the method outlined above for obtaining the frequency of a single Helmholtz resonator (or by other means, such as an application of Lagrange's equations), an equation can be derived by means of which the resonance frequencies of the double resonator can be calculated. This equation, which was first given by Rayleigh in 1870 [11], may be written in the form:

$$n^4 - n^2 \{(\mu + 1)n_1^2 + n_2^2\} + n_1^2 n_2^2 = 0 \quad . \quad . \quad . \quad . \quad (5)$$

in which n_1 is the frequency of the outer resonator, n_2 the frequency of the inner one, and μ is the ratio $\frac{c_1}{c^2}$. The roots of this equation, treated as a quadratic in n^2, give the squares of the resonance frequencies of the double resonator. It can also be shown [12] that the amplitude of the oscillations in the orifice c_2 corresponding to a pressure-variation F cos $2\pi nt$ at the mouth of the resonator is:

$$\left|\frac{dq_2}{dt}\right| = \frac{n n_1^2 c_2 F / 2\pi\rho}{\left[\{(n_1^2 - n^2)(n^2_\mu - n^2) - \mu n_1^4 - k_1 k_2 (n/\pi)^2\}^2 + (n/\pi)^2 \{k_1(n^2_\mu - n^2) + k_2(n_1^2 - n_2)\}^2\right]^{\frac{1}{2}}} \quad . \quad . \quad (6)$$

when k_1 and k_2 are the damping factors associated with the orifices c_1 and c_2, and for brevity n^2_μ is written for $n_2^2 + \mu n_1^2$. The velocity-magnification obtainable from the double resonator is the ratio of the maximum velocity in the inner orifice to the maximum velocity in the incident plane wave. If σ_2 is the cross-sectional area of the inner orifice, this ratio is:

$$\left(\frac{1}{\sigma_2}\left|\frac{dq_2}{dt}\right|\right)\Big/(F/ap).$$

The above equations allow us to calculate the velocity-magnification, say M_v^{iii}, obtainable from a double resonator in any particular case. As an example let us consider the case of a double resonator made from the two resonators (tuned to 256 vibrations per second) which have been previously mentioned. In this case we have $n_1 = n_2 = 256$. The orifice of one of these resonators was supposed to be wide and to have a conductance of 3 cm., while the orifice of the other was narrow with a conductance of 0·115 cm. The damping factor k_1 for the large orifice is calculated by means of the formula already given. The damping factor of the smaller orifice is 49 sec.$^{-1}$. From these values we find that the resonance frequencies of the double resonator are 232 and 282 vibrations per second, and that the way in which M_v^{iii} changes with the frequency of the incident wave is that shown in Fig. 4. The magnification for a tone of 256 is not much greater than with the small single resonator, being only about 389 against the previous value of 250. At the resonance frequencies, however, the magnification is much greater, being about 1,180 at the lower tone of 232 vibrations per second, and 1,020 at the upper tone of 282 vibrations per second.

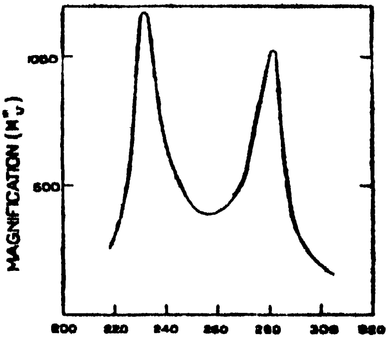

FIG. 4.

Variation of Magnification with frequency of sound.

It is obvious that to obtain good magnification for a tone of 256 vibrations per second it would be necessary to design a resonator having components with natural frequencies either both above or both below 256.

The greatest magnifications are obtained with this type of resonator when the coupling is loose, that is, when a condition is approached such that the simple theory is applicable and $M_v^{\text{iii}} = M_v^{\text{i}} . M_v^{\text{ii}}$. In the example quoted above, the coupling is fairly tight, so that the resonance frequencies are well separated. In order to reduce the coupling, it is necessary to make the orifice c_2 very small, and this, as explained in the case of single resonance, tends to increase the damping of the resonator on account of viscosity losses, so that there is no advantage to be gained by making the orifice less than a certain size. Moreover, the fact that the detector must be mounted in the orifice c_2 sets a limit to the amount by which it can be reduced. Much looser coupling can, however, be obtained than is indicated by the curve in Fig. 4, without seriously impairing the sensitiveness of the instrument.

There is another type of double resonator which it is convenient to use for certain purposes, in which the coupling can be varied in a different manner. This is the Boys pattern double resonator, first used by Prof. C. V. Boys for the construction of very sensitive Rayleigh disc instruments. The Boys resonator consists of a Helmholtz resonator combined with a resonator of the "stopped-pipe" variety, after the manner shown diagrammatically in Fig. 5. The detector is placed in the orifice of the Helmholtz resonator at *c*. The general behaviour of a double resonator of this kind is very similar to that of the Helmholtz pattern, although the theory of its action (which need not be given here) is a good deal more complicated. In order to obtain sensitiveness, the stopped pipe must have the same resonant tone—which may either be the fundamental or one of the overtones of the pipe—as the Helmholtz resonator.

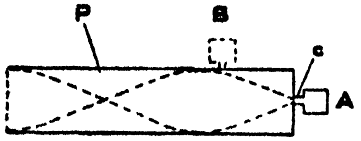

Fig. 5.
Boys Double Resonator.

The way in which the coupling can be varied in this type of resonator is as follows: It is found that the coupling is closest when the Helmholtz resonator is placed with its orifice through the wall of the pipe at a position which would normally be a node. Such a position, for example, is the closed end of the pipe, as at A, Fig. 5. If, however, the Helmholtz resonator is moved away from the closed end and towards a position where a loop is to be expected in the stopped pipe, the coupling is found to be loosened, as is evidenced by the coming together of the resonance frequencies, while at the same time the double resonator becomes more sensitive. After a certain position is passed (approximately three-quarters of the distance from node to loop), the sensitiveness again falls off, and in the vicinity of the loop there is practically no response, although the coupling is very loose. These properties of the Boys resonator are illustrated by the curves in Fig. 6, which are resonance curves taken by means of a hot-wire microphone [13]. The ordinates are proportional to the ohmic change in the resistance of the grid, and hence approximately to the energy of the forced vibration, while the abscissæ are the frequencies of the incident sound. The curve (*a*) is that which was observed when the Helmholtz resonator was at the closed end of the pipe, as at A, Fig. 5. The curve (*b*) corresponds to a position similar to B, Fig. 5, about three-quarters of the way to the first loop. Comparing (*b*) with (*a*) we see that the resonance peaks have come much closer together and the sensitiveness is much greater, although the response is over a shorter range of frequencies. The curve (*c*) shows the very small effect which is observed when the Helmholtz resonator is placed at a loop.

It is seen, therefore, that if a Boys double resonator is used, there is this alternative method of varying the coupling so as to obtain increased sensitiveness. In this method there is no necessity for the reduction of the orifice of the inner resonator to very small dimensions, and thus excessive losses due to viscosity may be avoided.

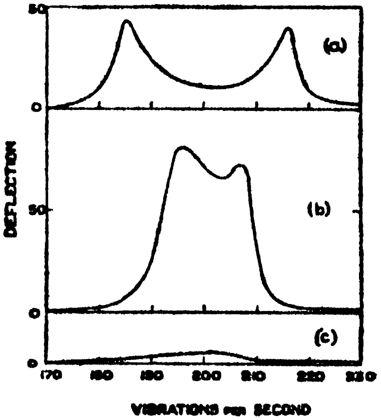

FIG. 6.

Resonance curves for Boys double Resonator.

In addition to increased sensitiveness, there is another advantage which a doubly resonated instrument possesses which should be mentioned here. In sensitive singly-resonated instruments the tuning is necessarily sharp, so that any slight mistuning between the sound to be observed and the instrument itself may result in a considerable change in the numerical value of the magnification, and this may give rise to errors in the measurements which are being made. Doubly resonated instruments, however, may be designed in such a way that the possibility of error on this account is to a great extent removed. This can be done by arranging for loose coupling so that the resonance frequencies are sufficiently close together for the trough between them, as shown in the resonance curve, not to fall very far below the peak values. The magnification for such a resonator is then approximately the same over a short range of frequencies between the peak positions, and if the frequency of the sound to be measured comes within this range, the errors due to inexact tuning are greatly minimised. The curve shown at (*b*), Fig. 6, is an example—though not a particularly good one—of fairly uniform magnification over a short range of frequencies, in this case from about 195 to 205 vibrations per second.

Enough has now been said to indicate the general nature of the problems which are being investigated in connection with the application of single and double resonance to the construction of sound-receiving instruments. The theory and use of such resonators is of great importance in the design of sensitive acoustical receivers, and the determination of the numerical value of the magnification is a necessary preliminary to the employment of such instruments for the measurement of sound-amplitudes in absolute units. For the measurement or comparison of sound-amplitudes, a doubly resonated instrument is generally to be preferred, both on account of its greater sensitiveness and broader tuning.

In conclusion, it may be noted that the interest attaching to the problems discussed above is not confined entirely to acoustics. Most coupled acoustical systems have their counterparts in electrical circuits and the same mathematical treatment is applicable to both sets of phenomena. The pursuit of these electrical and acoustical analogies is a matter of considerable interest, and may be attended with results beneficial to both sciences.

NOTES AND REFERENCES

1. *The Science of Musical Sounds*, p. 79 (1916).
2. Rayleigh, *Theory of Sound*, vol. ii (2nd ed.), pp. 194–5.
3. Rayleigh, *loc. cit.*, pp. 194–5; Lamb, *Dynamical Theory of Sound*, p. 265.
4. Rayleigh, *loc. cit.*, p. 178.
5. Tucker, W. S., and Paris, E. T., "A Selective Hot-wire Microphone," *Phil. Trans.*, A, vol. 221, pp. 389–430 (1921).
6. Tucker, W. S., and Paris, E. T., *loc. cit.*, p. 410.
7. *Phil. Mag.*, vol. xlv, pp. 926–34 (1923).
8. Cf. Tucker and Paris, *loc. cit.*, p. 401, where the term "magnification" was inadvertently applied to the ratio of the *current* in the neck to the *velocity* in the sound-wave. The meaning intended was that now given.
9. Described in *Nature*, vol. cx, pp. 42–5 (1922).
10. *Dictionary of Applied Physics*, vol. iii, p. 723.
11. *Theory of Sound*, vol. ii, p. 191; *Sci. Papers*, vol. i, p. 43.
12. *Proc. Roy. Soc.*, A, vol. ci, p. 408 (1922).
13. For details see *Phil. Mag.*, vol. xlviii, p. 783 (1924).

SOME REMARKS ON THE CONCEPTION OF INDIVIDUALITY IN BIOLOGY

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THE subject of this essay was originally chosen because the study of the colony-forming Cœlenterates had led me to seek after some understanding of the concept of Individuality in so far as it applied to Biology. I had no idea of the vastness of the subject, nor of its philosophical importance.

In September 1912 the Cambridge University Press published a book by Julian Huxley, late Lecturer of Balliol College, Oxford, on *The Individual in the Animal Kingdom.* He adopted as the " minimum " conception of an individual the possession of heterogeneous parts, functioning for the good of the whole, and independent of the forces of organic nature, an organism working after such a fashion that it, or a new individual formed from part of its substance, continued able to work in a similar way. Strange to say, Mr. Huxley does not refer in the book to the long lapse of time which had occurred since his grandfather, as a young man of twenty-seven, had introduced the subject of " Animal Individuality " at a lecture delivered before the Royal Institution,[1] nor does he refer to the great services which he rendered subsequently to philosophical Biology.

Professor Huxley had suggested that an individual animal was the " sum of the phenomena presented by a single life ; in other words, all those animal forms which proceed from a single egg." The individual was, he said, represented in the animal kingdom in various modes, modes which pass insensibly one into the other. Such a conception would make all the zooids of a gymnoblastic or calyptoblastic Hydrozoan, all the separate zooids budded off by a fresh-water Hydra, all the summer generations of the Aphis, together constitute a single individual. Professor Huxley himself was probably quite aware of the implication, though unfortunately only brief notes of the lecture were published, and he does not seem later to have returned specifically to the subject.

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[1] "Upon Animal Individuality," *Proceedings of the Royal Institution*, vol. i, 1851–4, pp. 184–9.

According to Le Dantec (*Théorie nouvelle de la vie*, [illegible]) "L'individu vivant est donc un corps qui ne peut être divisé sans que l'une au moins des parties résultant de la division perde la vie." Trembley, in his *Mémoires pour servir à l'Histoire d'un genre de Polypes d'eau douce* (1744), stated that a Hydra can be cut into a considerable number of pieces, and each piece, provided both ectoderm and endoderm are represented in it, will give rise by growth and regeneration to a complete zooid, though here there is a limit of size below which fragments of Hydra will not regenerate, even if they contain cells of both layers. According to Le Dantec, we could not then regard even a Hydra as an individual!

Spencer, who had preceded Le Dantec, in his *Principles of Biology* (1863), gave the first philosophical definition of Animal Individuality, by saying that we must regard "an individual as any centre or axis that is capable of carrying on independently that continuous adjustment of inner and outer relations which constitutes life." But the chloroplastids of higher plants are capable of independent growth and multiplication, thus exhibiting a good deal of individuality. Leucocytes, or white blood corpuscles, show a much greater degree of independence than most of the cells of the body, and can even live outside the body for a time, if kept in suitable culture media and at proper temperature. Do these, then, exhibit individuality?

The Yucca plant and a moth of the genus *Pronuba* are so closely related the one to the other that the moth can get food only from the Yucca, the Yucca can be fertilised only by that particular moth. "When the time comes for egg-laying, the moth flies to the Yucca, rakes up a large ball of pollen by means of a unique structure on her head, and then flies with the ball to another flower; there she sticks her long and curiously shaped ovipositor into the ovary of the flower, and lays her egg among the unfertilised seeds inside. Last, she lifts the pollen ball on to a special hollow on top of the stigma and pokes it firmly down. The pollen fertilises the ovules, of which there are about two hundred, and they start developing into seeds; meanwhile the caterpillar hatches and feeds at the expense of the seeds." About twenty seeds suffice to transform the egg into pupa and moth, and the remainder are left to grow into new Yucca plants. Two species, then, are absolutely dependent on each other for their continued existence. Julian Huxley's definition, carried to its logical conclusion, would concede individuality neither to the moth nor to the Yucca plant on which it feeds, but only to the two taken together and regarded as one in an indissoluble union. For neither plant nor moth taken apart from the other [illegible] "independent of the forces of organic nature." To speak of a combination of tree and insect as an individual reduces the term "individual" to an absurdity.

Haeckel (*Général Morphologie*, 1866) was the first to shed a clear light on the grades and progressive complexity of Organic Individuality. E. Perrier, in *Les Colonies Animales* (Paris, 1881), added widely to the subject. H. Bergson (*Creative Evolution*, translated into English 1911: Macmillan) considered an individual to be a "system, naturally isolated, naturally closed"; whilst Nietzsche laid stress on the individual's independence of the external world and its capacity to exist apart from it. "Accidents cannot happen to me, because all that would happen to me would be my own," says Zarathustra.

Writing in the *Cambridge Natural History* on the remarkable group of Cœlenterates known as the *Siphonophora*, Professor Hickson stated that "There is no convincing argument to support either the conception that the Siphonophoran body is a colony of individuals, nor that it is one individual with disjointed organs. These two conceptions are sometimes called the 'Poly-person'[1] and 'Poly-organ' theories respectively. The difficulty is caused by the impossibility of giving any satisfactory definition, in the case of the Hydrozoa, of the biological terms 'organ' and 'individual.' In the higher animals, where the correlation of parts is far more complex and essential than it is in the Cœlenterata, a definite limit to the scope of these terms can be laid down; but in the lower animals the conception of what is termed an 'organ' merges into that which is called an 'individual,' and no absolute boundary line between the two exists in Nature. The difficulty is therefore a permanent one, and, in using the expression 'colony' for the Siphonophoran body, it must be understood that it is used for convenience' sake rather than because it represents the only correct conception of the organisation of these remarkable Cœlenterates." Sir E. Ray Lankester would regard the Siphonophora as illustrating his "Theory of Eumerogenesis" (or perfect segment formation) in that "an original unit, like those which constitute the composite organism, has freely budded, and repeated its own structure, in the well-marked units which remain conjoined to form an arborescent or linear aggregate." He regards the polymorphic and dimorphic colonies of Hydrozoa as "synthesised eumeromorphs." The scope of this essay forbids any further discussion of these interesting points. Suffice it is to say that it would appear probable that the Nectocalyces, Gastrozooids, Dactylozooids, Hydrophyllia, and Pneumatophores may be referred to a common hydrosome or medusome form. The

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[1] This hybrid word should be discarded in favour of "multi-person."

Nectocalyces, for example, are provided with velum, and, usually, four radial and a circular canal. There is no manubrium, and the marginal tentacles are rudimentary or absent. The polymorphic colony of a Siphonophoran has undergone great division of labour, great structural changes having taken place in its component zooids in correlation with their special function.

The difficulty of explaining precisely what we mean by an individual is well illustrated by certain Madreporarian corals. The individuality of such Turbinoliidæ as *Caryophyllia* and *Flabellum* is probably comparable with that of an Eleutheroblastean. Such organisms may be described as illustrations of what are spoken of as individuals of the *second order*. The peculiarities of asexual reproduction, however, lead to many complications of this apparently simple type. Frequently a process of imperfect fission takes place, and the polyp, viewed from above, loses the circular shape found in *Goniastræa*, *Galanae*, and *Solenastræa*, and becomes band-shaped and much drawn out as in *Dichocœnia*. The mouth opening becomes divided up into a row of separate openings, but there is no further attempt at division into separate polyps. According to the Poly-organ theory we should have a number of polyps each possessing more than one mouth. The Poly-person theory would incline us to the view that each mouth belonged to a distinct individual. In the cœnenchyme we see that the undivided thecæ are not only elongated (*Dichocœnia*, *Favia*, etc.), but may become very greatly drawn out to pursue a tortuous course (*Mæandrina*, *Symphyllia*, etc.), thus giving the coral an appearance resembling that of the human brain. In the case of certain Antipatharia we are involved in still further difficulties. "In some genera there is a constriction of the zooid between the pairs of tentacles on each side of the axial mesenteries and the directive tentacles. This gives them the appearance of a division into three zooids with two tentacles apiece, one with a mouth and two without a mouth; and as the mouthless parts alone bear the gonads on the single axial mesentery, they have been called the "gastrozooids" and "gonozooids" respectively. All three zooids probably constitute together a single individual, in that the cavities of the so-called "gastrozooid" and "gonozooids" are continuous."

When we attempt to consider the individuality of the *Cestode* worms our difficulties are greater still. The adult tapeworm (*Tænia solium*) is ribbon-like, as its name implies, often attaining to a length of several yards. At one end is the sterile "head"[1] or scolex, attached to the intestinal wall; the remainder—the genital region or body—hangs freely in the

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[1] Possibly the "scolex" is the morphological posterior end.

interior. Attachment to the intestinal wall, rendered necessary by its peristaltic movements, is made possible by the presence of hooks and suckers on the scolex. The scolex is usually separated from the body by a slender neck; and the body consists of a long chain of segmented "proglottides." To begin with, each proglottid contains male reproductive organs comparable with those of the *Trematode*; female organs develop later, and self-fertilisation probably follows in due course. A remarkable *Cestode* feature is the entire absence of alimentary canal in both larval and adult forms. The muscular, nervous, and excretory systems which supply the proglottides are continuous throughout with those of the head.

Linnæus, Dubois, and Blumenbach believed that the strobilia was built up by the mutual attachment, in series, of numerous *Vermes cucurbitini* or free-living proglottides, thus constituting what is spoken of as an individual of the third order. Modern zoological opinion does not, however, support this view. Burmeister, Götte, Claus, and Perrier regard the strobilia as a metamerically segmented individual comparable to an Annelid (Poly-organ theory). Steenstrup, Leuckart, von Siebold, and van Beneden[1] look upon the proglottides as representing the sexual individuals of a linear colony (Poly-person theory.)

During the life-history of *Aurelia*, it will be remembered how, early in the winter, the Scyphistoma stage became encircled by ring-like constrictions, ultimately being divided up into a pile of strobilia, consisting essentially of a number of saucer-like bodies one on top of the other, and how, one by one, these strobilia broke off and swam away in the form of small eight-lobed, star-shaped ephyræ. Under the microscope, these ephyræ showed a characteristic sensory tentacle situated in a small recess at the end of each of the eight arms. The spaces between these arms were gradually obliterated by specially active growth in these regions, until the circular outline of the adult *Aurelia* was attained.

It might seem reasonable then to compare the *Cestode* "colony" with the *Scyphozoan* Scyphistoma, the proglottides budded off from the neck being comparable with the young ephyræ budded off from the original Scyphistoma. What right, however, have we to regard the Cestode proglottides as "individuals"? A single proglottid cannot be considered as "the total product of a fertilised ovum," yet neither can a single aphid nor a young *Hydra viridis* produced by gemmation!—and these, we believe, can rightly be regarded as individuals. Is a single proglottid able to carry on inde-

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[1] The question of the nature of the Cestode body and larvæ is discussed by Braun in Bronn's *Thierreich, Cestoda* (Bd. IV, Pl. 38–45).

pendently that continuous adjustment of inner to outer relations which constitutes what we call life? We are told that when a proglottis of "*Calliobothrium*" approaches maturity, it separates from the parent, the broken ends of muscles, nerves, and excretory vessels quickly heal, and, if it remains in the intestine of the host, it is capable of further growth and fairly active movement. Van Beneden in *Les Vers Cestoïdes* (1850) states that in growth it may equal or even exceed its parent. Facts such as these would appear to support the theory, held by Steenstrup and others, of the colonial nature of the *Cestoda*. Yet the continuity of the muscular, nervous, and excretory systems, together with other anatomical facts, would lead to its rejection. Are Lang and Hatschek, then, nearer to the truth in the intermediate position which they have taken? Lang holds that the "formation of the joints of a tape-worm from a small fixed 'scolex' is not only largely comparable with the strobilation of a scyphistoma and the consequent formation of a pile of medusæ, as in the life-history of *Aurelia*, but that both processes have arisen from the power of regenerating the necessary organs in each of the new segments. The result in both cases is the rapid formation of a number of joints, which gradually separate from the parent, to carry the eggs and young to new stations."

The more closely the problem of biological individuality is considered, the more one realises the futility of framing any satisfactory definition of the term "individual" which should prove applicable to the whole animal and vegetable kingdom. It seems to me that the difficulty is lessened if, instead of speaking of organisms and groups of organisms as "individuals" of the first, second, third, or higher orders, in the more complex cases we speak of the *possession of individuality, and restrict the term "individual"* to those cases which come within what is, I believe, Professor Hickson's definition—namely, that an individual is a living organism which "shows discontinuity in time and space." If we can reasonably speak of *a* millepore, *a* physophoran, *a* tapeworm, the very use of the word "a" implies something which can be considered as a whole and therefore, in that sense, as "an individual." We should then be using the word as it would be used by the man in the street. If we asked for *a* millepore, or *a* physophoran, a "colony" would be brought to us, then the colony, and not the separate organisms of which it is composed, is the *individual*.

The use of such alternative terms—either an individual or the possession of individuality—seems to me not only to be in line with the current terminology of the ordinary man, who would regard a family, a sect, a nation, etc., as possessing individuality but not as individuals, but to resolve many of the apparent absurdities which resulted from the application to all cases alike of the various definitions of the one term—"individual." Though it is difficult, for example, to regard the Yucca plant and the moth as together constituting *an* individual, we can think of the moth as so closely bound up in its existence with the plant that they do afford an instance of the *possession of a certain type of individuality.*

Individuality is an intangible phenomenon. Nature recognises no boundary lines. There is a continuous gradation from cell to tissue, tissue to organ, organ to organism. Organic evolution seems to consist in a process of progressive integration —a progressive merging—a progressive co-operation, accompanied by division of labour, whereby individuals of a lower order combine to form individuals of a higher order. The unicellular Protozoan, *Amœba,* so frequently found creeping about in the mud at the bottom of ditches and ponds, though exhibiting within the narrow limits of their jelly-like bodies a considerable amount of structural differentiation, may be regarded as individuals, *i.e.* of the *first or lowest order.* There is little or no differentiation of labour (?), and the individual cell units remain nearly, or almost, independent of one another. Amongst the Protophyta, an individual of the first order is found in *Hæmatococcus pluvialis,* which occurs in temporary pools of stagnant rain water. These individuals are independent cells, each performing alone all the essential functions of life; in the words of Herbert Spencer, they are " capable of carrying on independently that continuous adjustment of inner to outer relations which constitutes what we call life."

The principle of co-operation of different organic units is illustrated by the process of colony formation met with in certain Protozoa and Protophyta. *Hæmatococcus,* mentioned above, may be taken as the starting-point of our series. This form is always solitary, the two individuals separating completely from one another after each cell division. In the familiar fresh-water *Volvox,* on the other hand, the individual cells are arranged side by side in the gelatinous wall of a hollow sphere. Possibly it was this habit of colony formation which led to the origin of the Metazoa and Metaphyta from unicellular ancestors. The component cells of such a colony may become gradually integrated, the process being accompanied by marked differentiation and division of labour. Such a colony may be said to possess individuality of the *second order.* The result of such differentiation and specialisation is that the various functions of the colony are more efficiently and economically performed. The old individuals of the first order were able to specialise in different directions, but this could only take place at the expense of their losing their old individuality. Thus, in the fresh-water *Hydra*, the ectodermal cells become protective and muscular, and the endodermal cells glandular, whilst the interstitial cells remain comparatively undifferentiated, persisting, as it were, in a " young condition " not yet having developed the various characteristics of the myo-epithelial cells. The different " individuals " are no longer able to live independent lives, in that they cannot now perform for themselves individually all the functions that are necessary for their existence. If separated from one another, they will perish. In course of time this division of labour leads to that astounding complexity of structure found to be so characteristic of the higher Metazoa and Metaphyta.

One step farther. Young Hydras produced by gemmation are usually detached from their parents before they themselves produce buds ; but in *Hydra oligactis*, and numerous Calyptoblastea and Gymnoblastea, the buds often remain attached to the parent after they themselves have formed buds, in which case a small colony is produced. This constitutes the possession of individuality of the *third order*. We have here what we might crudely describe as a " colony of colonies," in that each individual zooid is in itself the morphological equivalent of an individual of the second order, such an Eleutheroblastean as *Hydra viridis*. In many cases, however, the process of integration and redifferentiation amongst the various units has been so great as to hide, almost entirely, all traces of their origin. It has been said that the human head—if we traced back far enough—could be shown to have consisted originally of a number of fused segments, each of which was an individual belonging to a linear colony.

The mutual dependence of such a social organisation as that of the Bee or Termites results in the possession of what we might call the " super-individuality " of a *fourth order*.

It is impossible to include, within the limits of this article, all aspects of this widespread subject : only a few outstanding points by well-known workers have been included, and particularly those points referring to the purposive co-ordination of structural parts and resultant behaviour, which come within the range of the systematic zoologist. No account has therefore been taken of the work of Prof. Child (*Individuality in Organisms*, 1915), concerning the intensity and range of physico-chemical changes, which he considers determine the limits of the individual. According to Prof. Child, the starting-point of the individual lies not in a certain organisation, but in a certain reaction-system, individuation consisting in a relation of dominance and subordination. " Whenever a new metabolic gradient of sufficiently high rate is established by an external factor, a new individuation occurs." His conception of an individual organism is mechanistic and based on physico-chemical dynamics, rather than structural, and based on psycho-physiology, like those with which we have previously dealt.

As with lower animal life, so with man, we can see progressive " orders " of individuality starting with the primitive, and probably arboreal, savage, whose independent existence was maintained by the work of members of his immediate family, passing to a condition when security was sought and found by the combination of families into larger communities. Thence to the condition of agricultural life, where family groups or small communities were collected into villages with different occupations. With facilities for trade, villages grew into towns. With the need for further protection from enemies and rivals, towns became massed into countries or nations. These nations became empires. The possession of super-individuality of the highest order will be reached when empires and nations are banded together in one great league to resist the inroads of all those destructive agencies which threaten the existence of the race itself.

SOIL INSECTS[1]

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I. Review of Past Work

The undertaking of comprehensive insect surveys probably first originated with the zoologists of the Illinois State Laboratory of Natural History under the influence and guidance of its director, Stephen A. Forbes, and there has been produced from time to time by the workers of this school a series of excellent monographs dealing with the ecological relationships of the insects and other invertebrates of the State of Illinois. Apparently the principle underlying these surveys has been to preserve for the future a record of the fauna of the State in its transformation from a wilderness to a prosperous agricultural and industrial country. Adams [1] has explained that his ecological study of prairie and forest invertebrates was made with the idea of reporting upon representative patches of prairie and forest in a manner which would preserve some records of the present condition of the prairie and forest. For the same reason the work of Shelford [23] and Vestal [27] assumes a valuable significance which is likely to be enhanced as comparable studies in similar areas are carried out. Two European workers, Diem [13] and Holdaus [15], in 1903 and 1910 respectively, published brief records of the fauna of the soil.

In a comparison of the work accomplished by the American ecologists with that of the British, an important difference becomes apparent. The areas which were investigated in Illinois occupied a much larger territory than those in England, and, as a result, the Illinois workers have been able to arrive at conclusions of a more generalised type than were possible with the more restricted studies of the British workers. The prairies and forests of North America cover vast stretches throughout which climatic conditions are fairly constant within the limits of certain well-defined zones. Thus it is that inferences elicited from the study of the faunistic composition of a sample of prairie or forest at some specific area within a particular zone are likely to apply to other similar areas within the same zone, although they may be widely separate from each other. The British workers attempted a more intensive type of investigation within very limited areas in urban or agricultural districts, where natural conditions no longer prevailed. It soon became evident that under these conditions it was practically impossible to treat of soil insects as a homogeneous entity governed by a measurable set of environmental factors. The facies of an agricultural district is continually changed by cultivation, so that the soil never attains to a condition of stable equilibrium, except, perhaps, in the case of permanent pasture. Even in the case of grasslands of long standing it was recognised that the soil-insect population varied considerably, its composition being appreciably affected by migration of species from adjoining arable land and *vice versa.* The rotational system of agricultural practice has produced an ever-changing physical and organic environment, and the composition of the soil-insect population varies proportionately with the transformations in this environment. In that the transformations generally occur regularly and in orderly fashion, the annual variations are gradual, not abrupt, and comparatively small. In passing from the primeval conditions of undisturbed nature marked by a condition of equilibrium, through the transitional period of a one-crop system, which obtains in new countries such as the prairies of Western Canada, to the rotational system of older lands, agriculturists have adopted the most powerful single instrument in the restriction of the undue increase of insect pests that has yet been provided.

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[1] **Read before Sections D and M, British Association, Toronto meetings, August 8, 1924, as part of the discussion on "Soil Population."**

In his survey of the soil fauna of agricultural land, Buckle [2], recognising the difficulty of interpreting the faunistic composition in terms of the numerous variable physical factors of the environment, suggested the possibility of its correlation with soil-types alone, such as sands, clays, and loams. Interpretations based on such a restricted basis would possess little of value, as the environment cannot be regarded as other than a complex in which the fluctuation of any single factor may affect one or all of the others.

The first soil-insect survey in Britain was carried out by the author [3] in a small area in the vicinity of Manchester, and was amplified by a later study [4] at Holmes Chapel, Cheshire. The area discussed in the first of these studies, surrounded as it was by urban conditions, did not offer any information that could be strictly applied to agricultural conditions. The investigation, however, served its purpose in that it presented for the first time a statement of the problems of soil insects viewed as a corporate whole, their biological relationships both amongst themselves and to their physical environment, the soil and vegetation. At the same time, a working definition of the term *soil insect* was presented which has formed a basis for the prosecution of the studies of later biologists in this field of activity. Here, too, the method of the sample system was introduced for the analysis of the soil fauna, and by its use computations of the composition of the fauna were obtained. The sample method is still employed, but the tedious effort of manual examination of soil samples has been greatly relieved by the introduction of a special apparatus by Morris [20], whereby a fractional separation of insects and other invertebrates from the soil is achieved by means of a current of water led through a linear series of three sieves. The uppermost sieve containing the soil sample has a coarser mesh than the remaining two, that of the lowest being the finest. This one serves to retain only the smallest insects and the finer fractions of soil. The larger soil insects together with the coarser particles are retained by the two upper sieves and can be readily extracted. The underlying working principle of separation rests on the variation in size of soil insects as well as of the particles composing the soil. An apparatus patterned on that of Morris is being used by the representative of the Canadian Entomological Branch in an insect investigation of prairie soils in Saskatchewan.

So far as the British work on soil insects is concerned, much of the credit of their investigation is due to Prof. S. J. Hickson, with whom the idea originated. At his suggestion the author [3] began his researches in 1912, and the surveys of Morris and Buckle [2] that have followed are also products of Hickson's department. Morris [19] has continued his investigations at Rothamsted.

II. Soil Insects and their Habitat

The term *soil insect* was defined by the author [3] in 1913 as comprising all insects which at one time or another in the course of development from the egg to the imago spend some stage or stages of their life-histories either on or beneath the surface of the soil. This definition at once apprises us that soil insects do not belong to any particular genus, family, or order of insects. With a few notable exceptions, such as the truly aquatic Ephemeroptera, Trichoptera, and Odonata, the parasitic Mallophaga, Siphunculata, and Aphaniptera, all the principal orders contain a lesser or greater number of species that answer to the above definition. Briefly enumerated, these orders are the Apterygota, Isoptera, Mecaptera, Thysanoptera, Hemiptera, Dermaptera, Orthoptera, Coleoptera, Lepidoptera, Hymenoptera, and Diptera. Of the more extensive orders of Hemiptera, Orthoptera, Coleoptera, Lepidoptera, Hymenoptera, and Diptera, the Orthoptera and Coleoptera probably contain a larger proportion of species, the various metamorphic stages of which are more or less closely identified with the soil throughout the life of the individual. In the Orthoptera there are numerous species of the families Gryllidæ and Acridiidæ, which spend as many as ten months or more associated with the soil or its immediate covering of herbage and but two months or less in the aerial stratum above the soil as adults. As an example, the acridiid species, *Melanoplus atlanis*, the Lesser Migratory Locust, will serve. Likewise in the Coleoptera, and more especially in the families Scarabæidæ, Silphidæ, Cicindelidæ, Carabidæ, Staphylinidæ, and Curculionidæ, numerous species spend the complete life-history in or on the soil. Many species of Elateridæ oviposit in the soil where the larval and pupal stages are also passed. The adults occur either on the surface of the soil or on the herbage above the surface. In the Lepidoptera and Diptera soil insects are perhaps most commonly represented in the Noctuidæ of the former order, whilst in the latter they will be found variously distributed in the Bibionidæ, Tipulidæ, Mycetophilidæ, Leptidæ, Tabanidæ, Empidæ, Muscidæ, Anthomyiidæ, to mention but a few families. Examination of the life-histories of many soil-insects will show that the adults are frequently to be found in the aerial strata above the soil. By its active powers of flight the adult or reproductive phase is enabled to maintain the range of distribution of the species by migrating from one locality to another where suitable conditions for breeding occur.

It must be recognised that the soil offers for those insect species which frequent it the optimum environmental conditions for the orderly maintenance of their vital activities. For many soft-bodies insects, such as the larvæ of Cicindelidæ and Sphecoidea, it offers a medium in which burrows can be formed for protection against untoward circumstances.

The true index of an animal habitat is its suitability for breeding as well as for feeding, and of the two the former is probably the more important. If we adhere strictly to this definition of habitat, the number of species which our definition of soil insect includes would be greatly reduced. For instance, the true habitat of such typical parasites of Œstridæ is the mammalian host, on the hairs or in the nostrils of which they lay their eggs. When the larvæ have completed their development within the host, they emerge and drop to the ground, which offers a comparatively safe asylum for the resting pupal phase. So it is with many of the Hymenoptera that parasitise other insects. Many dipterous leaf-mining insects [4 and 5] likewise pupate in the soil. In these cases the crevices of the soil provide a friendly place of shelter, whilst the radical histolytic changes resulting in the development of the imago are completed with some guarantee of safety against attack by predaceous animals. Another particular instance of this aspect of the question of soil insects is furnished by the widely distributed Pear Thrips, *Tæniothrips inconsequens* [8], which lays its eggs in the tissues of the midribs and petioles of a variety of native and orchard trees. The nymphs, after feeding openly on the flowers and leaves, drop to the ground during the late summer, where they transform to prepupæ followed by the pupæ, from which the adults emerge in December under the conditions prevailing in Vancouver Island. The adults remain protected in the soil until the end of March, when, with the soil temperature rising to 45° Fahr., they desert their winter quarters in the soil and pass to the opening buds of their food-plants. Altogether, this insect spends almost seven months in the soil from September of one year to March of the following year. Nevertheless, in virtue of its breeding and feeding habits we should hesitate to include it among soil insects *stricto sensu*. Its presence in the soil is merely incidental to the occurrence of its proper food plants above the soil surface, and the duration of its soil phase does not necessarily argue for its classification with true soil insects. Other instances of a similar type might be cited, but in my investigations I have preferred to neglect the criteria of a habitat so as to include within the meaning of the term *soil insect* all species that are at any time associated with the soil, no matter whether the period of association is long or short.

It will be interesting, however, to enumerate a few species of insects that both breed and feed in or on the soil. These have been chosen at random, some of them occurring in Europe, others in North America. In each case the order precedes the species examples printed in italics.

Thysanura, *Campodea staphylinus*; Collembola, *Isotoma viridis*; Dermaptera, *Forficula auricularia*; Orthoptera, *Camnula pellucida*; Rhynchota, *Aphis maidi-radicis*; Mecaptera, *Panorpa communis*; Lepidoptera, *Porosagrotis orthogonia, Euxoa ochrogaster*; Coleoptera, *Nebria brevicollis, Ocypus olens, Aphodius fimetarius, Ludius æreipennis, Lachnosterna rugosa, Agriotes obscurus*; Diptera, *Tipula oleracea, Hylemyia brassicæ, Dilophus febrilis*; Hymenoptera, *Lasius niger americanus, Bombus terricola, Ammophila pictipennis.*

III. Adaptations of Soil Insects

Soil insects, derived as they are from widely varying orders, lack homogeneity. Amongst aquatic insects the range of structural modification and adaptation to a fluid environment is fairly wide, chiefly affecting the organs of locomotion and respiration. Legs become adapted for progression in water, and the respiratory system modified for the extraction of dissolved oxygen from the water in the more specialised forms. That there is often a distinct lack of resemblance both structurally and genetically in these modifications in the aquatic species of different orders supports the theory that the problem of aquatic existence has been solved in the different orders independently and probably at widely different times.

As compared with aquatic insects structural modifications in soil insects are comparatively few. Examination of the respiratory system of different species fails to reveal any striking peculiarities. The function of breathing is effected in a manner entirely identical with that of aerial forms. Generally speaking, the insect-bearing strata of the soil are penetated by the same mixture of gases that compose the air, which all terrestrial animals breathe. On account of the fact that fermentative processes in the soil may cause an undue increase in the proportion of carbon dioxide, it is possible that soil insects can resist for long periods the deleterious effects of an excess of carbon dioxide and a consequent decrease of oxygen. It is suggested by Adams [1], p. 116, that the white grubs, *Lachnosterna*, may be able to close their spiracles under such circumstances, thus retaining and conserving the supply of oxygen within the tracheæ and occluding the entrance of carbon dioxide.

As regards organs of locomotion there is a wide variation in the degree of their development, but the causes of differentiation are not to be sought successfully amongst the physical factors of the habitat so much as in the habits and behaviour of the insects themselves. Root-feeding dipterous and coleopterous maggots find in the plant tissues of their varied hosts a plentiful supply of rich nutriment which is readily available. As in many other species, which feed on decaying animal and vegetable substance, or are parasitic, degeneracy of the organs of locomotion ensues, this being but a particular instance of adaptation explicable on the grounds of an abundant food-supply, which obviates the necessity of active search for food-material. As contrasted with these degenerate forms there occur many surface-inhabiting cursorial species, in which the powers of locomotion are extraordinarily well developed to match their predaceous habits and facilitate their escape from danger. Examples of these are to be found in the Cicindelidæ and Carabidæ. Predatory soil insects are not, however, always endowed with well-developed organs of locomotion. The larvæ of Tabanidæ, which occur in the moist soil around ponds, merely possess stump-like prolegs, three or four pairs on each of the first seven abdominal segments. There is, however, a powerful body musculature, which enables these insects to force their way rapidly through the soil in their search for earthworms and soft-bodied insect larvæ.

Probably the most perfect adaptation amongst soil insects occurs in the curiously enlarged front legs of *Gryllotalpa*, mole-cricket, which are used for excavating their underground burrows. Fossorial wasps of the Super-family Sphecoidea, which are very rapid in the excavation of their burrows, do not depend on any special structural modifications in their work.

IV. ENVIRONMENTAL FACTORS THAT CONSTITUTE THE SOIL HABITAT

It is not my intention to discuss in detail the relationship of the various physical factors to the insect denizens of the soil, but merely to indicate how important is the consideration of some of these in any adequate treatment of the subject. It is evident that the soil offers to insects a habitat of comparative security, which is peculiarly suitable for soft-bodied larvæ or unprotected pupæ. Security, however, does not render a habitat acceptable to an organism, unless it can also adjust itself to the physical factors of its environment. The factors which exert a profound influence upon soil insects are temperature, humidity, and soil ventilation or aeration, which depend again upon soil texture and structure. Another factor of lesser importance is intensity of light, which remains practically constant in the recesses of the soil everywhere and is, therefore, not primarily determinative of faunistic composition. Still another, also of minor importance, is barometric pressure, but in that variations of pressure influence the percentages of atmospheric humidity this factor cannot be neglected entirely.

Russell [22] has said that the soil is a porous mass made up of a hard framework plastered over with a jelly (*of organic colloids*) containing chemically active substances, plant foods, and unstable organic compounds rich in stores of easily liberated energy, while the pores contain air and a considerable amount of water. Three distinct soil-types are recognisable, distinguished from each other by their texture, but not sharply so. First, there are the sandy soils, consisting chiefly of inert silica with about 6 per cent. of clay. Second, there are the loams, with about 6 to 15 per cent. of clay, 40 to 60 per cent. of silts, and 20 to 50 per cent. of fine sand. Lastly, there are the clays, sticky soils characterised by their capacity for retention of moisture, but becoming hard-baked in dry weather. They contain about 25 per cent. or less of clay. Of the three, the loams are the most fertile on account of the presence of a more abundant and readily available food-supply for plants. Sandy soils are characterised by their warmth and earliness as judged by more rapid maturing of crops, whilst clay soils are late, cold, and difficult to work.

Insect life is most abundant in a shallow vertical layer extending from the surface of the soil to a depth of about six inches. The greater majority occur in the first three inches, a fact verified by the investigations of myself [3 and 4] and Morris [19], and there is an appreciable decrease with depth. The soil stratum occupied by insects is roughly that of cultivation, and the progressive attenuation would seem to indicate that soil insects do not thrive except under those conditions of their environment which best foster vegetative growth, apart from light, to which soil insects react negatively.

We shall now briefly discuss the physical factors of the soil environment.

1. *Temperature.*—The temperatures prevailing in the first six inches of the soil with the exception of the top half-inch are subject to lesser fluctuations between daily minima and maxima than is the air, and wherever there is a covering screen of vegetation the variation is even less than on bare fallow surfaces. The moisture content of a soil strongly influences its temperature in that heat travels more quickly through a moist soil than a dry one, and a moist soil is more uniform in temperature. Insects are repelled from a dry, warm soil partly because of the increased temperature, but also partly because of the deficiency of the moisture factor. This I have observed both by actual observation in the field and by experiment. Samples of soil were taken from a bare fallow in summer, when the temperature at the surface of the soil was 90° Fahr. No insects occurred in the first inch of twelve samples examined, and very few at a depth of three inches. Beneath this, wireworms and a species of small scarabacid larva were common. In the laboratory a sample of soil twelve inches square was placed in an insulated wooden box. Thirty wireworms were placed on the surface of the sample and the surface gradually warmed from above by an electric heater. As the temperature advanced at the surface from 65° Fahr. to 120° Fahr., the temperature at three and six inches also gradually increased, until after three hours, with surface temperature of 120° Fahr.,

that at three inches was 90° and at six inches 70° Fahr. The sample was then examined, when it was found that the wireworms had the following vertical distribution: three inches, 2; four inches, 5; five inches, 8; six inches, 10; seven inches, 5. In a control sample of similar dimensions and with the same number of wireworms, after three hours 25 were found to occur in the first inch and 5 in the second.

Below a temperature of 45° Fahr. most soil insects become inactive, and passivity becomes more pronounced as the temperature descends. As the temperature is raised above 45° Fahr. activity is reassumed, until the critical temperature is reached beyond which death ensues. It is probable that for each species there is a temperature range within which the life-processes proceed normally, activity increasing or decreasing according as the temperature rises and falls. Above or below this range, which is probably constant for each species, metabolism of the organism finally ceases with fatal results. It has been suggested by the author [3] that the marked faculty, which many hibernating soil insects possess, of resisting freezing temperatures may be due to the high concentration of their body juices. Increase of concentration determines a lowering of the freezing-point. The phenomenon may not lend itself to such an easy explanation as this, and the question would offer a fruitful field of research to the qualified investigator who cares to enter it.

Whilst it is generally accepted that with the onset of winter, soil insects desert the superficial layer of the soil for greater depths to escape the cold, Morris [19] in his work on the insect fauna of arable land at Rothamsted remarks that no seasonal variation in the distribution in depth of the soil fauna was observed. Vertical migration is a function of the severity of the climatic conditions. As Morris's investigation lasted for one year only, and his paper shows no record of the prevailing temperatures and other climatic factors, it would be impossible to arrive at any conclusions based upon the data presented. In my investigations in Cheshire [6], in 1913–14, the lowest average temperature recorded in the soil at six inches was 38·9° Fahr. in January 1913, and 40·2° Fahr. in March 1914. The highest average temperature was 59·1° Fahr. in August 1913. During both winters about 70 per cent. of all forms were found at an average depth of four inches as compared with more than 70 per cent. in the first three inches during the summer.

The vertical seasonal migration of soil insects is less pronounced in England with its more equable insular climate than occurs under the more extreme, continental, climatic conditions which Canada enjoys. On the prairies the temperature of the first six inches of soil falls to 10° Fahr. below zero during the winter. At three inches, temperatures of $-20°$ are recorded. Frost penetrates the soil to a depth of at least six feet. Criddle [9] records that the grubs of *Lachnosterna rubosa* hibernate at an average depth of seventy-four inches, whilst the adult burrows to a depth of sixteen to forty-seven inches. The larvæ thus penetrate to a depth beyond the frost-line, whilst the adults, penetrating less deeply, nevertheless experience less extreme cold than prevails near the surface. Even although many hibernating insects fail to penetrate beneath the frost-line, the farther they migrate beneath the surface, the more stable will be the temperatures encountered and the less the risks of subjection to the injurious effects of alternate freezing and thawing.

In Vancouver Island, where the range of soil temperatures is very similar to that of England, the Pear Thrips, *Tæniothrips inconsequens* [8], hibernates at depths varying from six to ten inches and emerges from the soil at the end of March and beginning of April, when the temperature at the surface has risen above 45° Fahr.

2. *Humidity.*—The soil receives water from the rain and from the subsoil, but it also loses water by evaporation and drainage. As Russell [22] remarks, the actual amount present in the soil at any time, therefore, depends on several factors, as it obviously represents the balance of gains over losses. The blanket of humid air, which accumulates under a cover of vegetation, tends to retard evaporation and conserve soil moisture. At the same time this living vegetative covering causes loss of moisture both through direct evaporation and absorption much faster than a bare moist soil. In the latter the moisture-content tends to be conserved by the maintenance of a surface mulch. Different soils have not an equal capacity for water, which increases with the decrease in size of the soil particles and varies with the humus ratio. Both loams and clays contain more water than sands and are more retentive of it.

Undoubtedly the optimum conditions of soil moisture for insects is a variable, concerning which there is practically no accurate information. In a general fashion we know that different soil insects respond differently to varying degrees of humidity. Many species of larval Tipulidæ and Tabanidæ occur only in soils near lakes and ponds that are continually saturated with moisture. On the other hand, the Cicindelidæ and Sphecoidea select a light sandy soil, and the former may frequently be seen scurrying over hot, exposed sands, during days when the shade temperatures in the summer are hovering around 90° Fahr. Fossorial wasps dig their burrows in light sands, but they are carried to a depth where the sand retains sufficient moisture to lend support to the walls.

The dry soil mulch of a bare fallow does not offer favourable moisture conditions for insects, but beneath the mulch insect life is often abundant. This I have observed in the case of the Pale Western Cutworm, *Porosagrotis orthogonia*, a pest of wheat in Montana, Southern Alberta, and Saskatchewan. This species appears to be characteristic of arid regions, whilst the Red-backed Cutworm, *Euxoa ochrogaster*, also a pest of wheat, is more prevalent in the more humid northern parts of Saskatchewan and Alberta.

3. *Soil Ventilation.*—Soil ventilation or soil breathing is determined by temperature, humidity, and evaporating conditions. A high soil temperature is conducive to a rapid diffusion of air and carbon dioxide through the soil interstices. The soil oxygen is derived from the air, whilst the carbon dioxide may be derived from the disintegration of complex organic compounds in the soil itself or from the carbon dioxide of the air carried in soluble form into the soil with rain water. Dry soil contains from 35 to 50 per cent. of its volume of air, and in moist or wet soils the air spaces are replaced by water. As the water passes downwards with drainage, the soil interstices at the surface are again filled with air. Thus drainage and the flow of water through the soil facilitate ventilation, which is influenced in large measure by the porosity of the soil. The rate of diffusion of soil gases is approximately proportional to the square of the porosity.

Adams [1] states : " In view of the dominance of carbon dioxide in soils, we may anticipate that many of the animals living in them possess some of the characteristics of the plants, bacteria, fungi, etc., which are active in such soils. The anaerobic forms live without free oxygen, others live only where oxygen is present. The animals which thrive in the soil are likely to be those which tolerate a large amount of carbon dioxide and are able to use a relatively small amount of oxygen, at least for considerable intervals, as when the soil is wet during prolonged rains." Again the same author remarks : " The optimum soil habitat is therefore determined, to a very important degree, by the proper ratio or balance between the amount of available oxygen and the amount of carbon dioxide which can be endured without injury." Loamy soils of a medium texture have a richer insect fauna than sandy soils and clays. Mechanical obstruction to progression on account of their close texture, as well as comparative stagnation in the conditions of aeration, renders the clays an unsuitable medium for insect activity.

It is probable that many soil insects can resist the toxic effects of excessive amounts of carbon dioxide by closure of the spiracles, just as many of them can endure submersion for prolonged periods without injury. Reduction in the available supply of oxygen diminishes the rate of metabolism of the organism and stimulates passivity. Activity is once again resumed when the supply of oxygen becomes normal.

From the foregoing remarks it will be apparent how little accurate information we possess concerning the environment of soil insects. Experiments concerning the influence of the various physical factors on the insect inhabitants have been few and far between, and until this deficiency is made good, our knowledge must necessarily remain restricted. Concisely, we may describe the environment as that stratum occupied by soil insects, which coincides roughly with the zone of cultivation and root-growth. From the subsoil, insects are repelled by a lack of food and deficient ventilation. From the aerial strata above, soil insects are likewise repelled by the greater variability in range of temperature and humidity, with which must be considered the degree of intensity of light.

V. Soil Insects and Soil Fertility

Earthworms have been accredited with the function of natural agents in soil cultivation, this in virtue of their habit of burrowing in the soil. They are thus said to assist in the processes of soil ventilation and drainage. To them has also been attributed a rôle in the maintenance of soil fertility by reason of their habit of eating the soil for the organic substances which it contains, and thus the mineral substances are rendered more readily available for the use of plants as food. The humus content of the soil is considerably increased by their habit of dragging decaying leaves and other vegetable débris into their burrows.

That the fertility of the soil is not merely a function of the numbers of earthworms which a soil may contain is evidenced by the high degree of fertility of the soils of the wheat-lands of Saskatchewan, where the earthworm is absent. It is unlikely that soil insects contribute to fertility, although their habit of burrowing may aid in soil aeration. Some few insects, such as leather-jackets, may devour the soil for the sake of its organic material, and even in the food-canal of larvæ of *Chrysons* of supposedly predaceous habits I have discovered soil particles. The soil-devouring habit is, however, so restricted among insects that they cannot be considered as agents in the production of plant food to the same extent as earthworms.

It has been frequently suggested that soil insects in virtue of their great numerical abundance might be found to prove themselves an important reserve and source of nitrogen. In order to test this theory, Morris [19] determined the nitrogen content of several of the more common families of soil insects, Annelids and Myriapods. As a result of his computations he concluded that in manured soils, where insects were more abundant, the total nitrogen content of the fauna was 16·2 lb., as contrasted with 7·5 lb. in an acre of unmanured soil, where the numbers were less. These amounts of nitrogen were considered too small to be a factor in fertility. Furthermore, the soil insect fauna on account of its instability, its migrations from the soil to the aerial stratum with the completion of metamorphosis, is a quantity too variable upon which to base other than nominal calculations of this kind.

VI. Injurious Soil Insects and their Control

From the economic standpoint soil insects may be classified into three groups, beneficial, noxious, and innocuous. In the first class we include, for example, species of Ichneumonidæ and Braconidæ that are parasitic on such soil insects as cutworms, the predatory Carabidæ and the scavenging Scarabæidæ, to name but a few families. Examples of the second class are to be found in the Elateridæ, Noctuidæ, some Scarabaeidæ and Curculionidæ, Tipulidæ. Among innocuous forms are included merely incidental species that find in the soil a safe retreat where they pupate. In certain cases an injurious species may be entirely harmless during its soil phases, as is the case of the Colorado Potato-Beetle, *Leptinotarsa decemlineata*, of which the pupæ and hibernating adults are found in the soil.

The control of harmful soil insects has always been fraught with much difficulty. Their attacks are carried out under the effective cover of their environment, and, entrenched in the soil, they are not readily combated by the ordinary methods of inhibition. Varying with the different injurious species and their habits, the following methods of attack are at present employed: agricultural practices such as systems of cultivation of the soil and rotation of crops; attractive baits with which poisons may or may not be mingled; soluble poisons; soil fumigants and insecticides; and chemical fertilisers. We shall briefly discuss each one of these methods and remark upon its efficacy.

1. *Agricultural Practices.*—These methods are employed particularly in the case of those pests that attack field crops. Fields that are infested with wireworms and white grubs should be ploughed so as to bring them to the surface, where they are exposed to the attacks of insectivorous birds and

adverse weather conditions. For the control of *Corymbites noxius* and *C. inflatus* of the dry-farming region of the North-western States, where wheat alternates with summer fallow, the following practice has been recommended by Hyslop [16]. The summer fallow is harrowed as early as possible in the spring in order to produce a mulch and thus conserve the accumulated moisture of winter. The harrowing is continued as often as is necessary in order to maintain the mulch and keep down weeds. The summer fallow is then ploughed in July or early in August and immediately harrowed. Fields which have borne a crop are ploughed as soon as the crop is removed. This same method would be applicable to the control of the two destructive species of wireworms that are common in the wheat-growing districts of Saskatchewan, namely *Ludius æreipennis* and *Corymbites nocturnus*. Unfortunately, there is practically no evidence that ploughing is really an effective measure of control for wireworms.

For the control of white grubs, *Lachnosterna* spp., in Manitoba, Criddle [9] advises ploughing between May 14 and July 1, when the eggs, larvæ, and pupæ occur above the plough-line. Before and after these dates they descend beneath the plough-line and cannot be reached.

On the prairies the plough is effectively used for burying the egg-pods of grasshoppers, *Camnula pellucida*, *Melanoplus atlanis* [10]. The egg-pods occur at a depth of three-quarters of an inch and are deposited late in the summer either in grassland or stubble fields. By ploughing the infested ground in the autumn to a depth of not less than six inches and turning the furrow so that the whole upper side is well covered, the nymphs on hatching in the spring are prevented from reaching the surface.

2. *Baits.*—These are substances either used singly or consisting of a mixture of materials that prove attractive to pests. In this method of control advantage is taken of the chemotropic response of the insect to one or several ingredients, if it be a mixture, and the insect is killed either by poisons or by a purely physical method. For wireworms, Treherne [26] advocates the use of sliced potatoes introduced into the soil at a depth of a few inches and left undisturbed for a period of five to seven days. The position of the bait is indicated by a wire. When removed, the bait with attached wireworms is plunged in boiling water and the pest destroyed.

Alternatively, Treherne (*ibid.*) recommends the use of balls of wheat or rice-shorts, rice-bran, or corn-meal. These materials are first roasted in pans and then moistened and moulded into a rounded form by hand. They are used in the same fashion as the potato-bait.

Both of these baits are inexpensive, but could only be economically used in small fields.

The bait method is also employed for the control of the Onion Maggot, *Hylemyia antiqua* [25], which lays its eggs either on the stems of the host plant near the soil or on the soil itself. The maggots on hatching enter the young developing bulbs. For the adult of this species there is a pre-oviposition period of about ten days, during which it can be profitably controlled by a bait mixture consisting of sodium arsenite dissolved in water and sweetened with molasses. The liquid is sprinkled in large drops over the foliage of the onions and on the surface of the soil, proving very attractive to the flies. The treatment is repeated four or five times at intervals of one week, as the emergence of the flies is distributed over a period of several weeks.

Against the ravages of cutworms and grasshoppers in North America the use of poison-bait mixtures has produced most satisfactory results. They are composed of bran, or other similar substances, that has been sweetened by molasses and poisoned with an arsenical compound. In the control of grasshoppers some flavouring substance such as salt or fruit juice is added to accentuate the attractive properties of the bait. In large outbreaks the bait mixtures are broadcasted on the surface of the soil infested by the pests.

3. *Wet Poisons.*—Corrosive sublimate in the proportion of one ounce to ten gallons of water has been employed with a large measure of success by Treherne [25] and others in the control of the Cabbage Root Maggot, *Hylemyia brassicæ.* This insect deposits its eggs on the stems of the cabbage or other related plants or on the adjoining soil. The maggots on emerging burrow into the stem of the host-plant. The soil and the stems on which the eggs are deposited are treated with the poison liquid and both these and the emerging maggots are destroyed.

The introduction of corrosive sublimate has been a distinct advance on the use of the tarred felt-paper discs, which were fitted around the base of the young plants to repel the ovipositing adults.

4. *Soil Fumigants and Insecticides.*—In France carbon disulphide has been recommended for the control of the grape *Phylloxera* and other underground insects. According to Davis [11], who cites Leach, carbon disulphide has been found to be very effective for destroying woolly apple aphis, *Eriosoma lanigera.* For the control of general crop pests such as white grubs, *Lachnosterna* spp., its use has been found to be impractical on account of its prohibitive price. In a series of experiments carried out in New Jersey under the direction of Headlee,

Davis says that control of white grubs in a lawn was secured by using carbon disulphide in the proportion of three-quarters of an ounce for every square foot. The cost was \$272 (£54) per acre.

Carbon disulphide finds its best use in the control of insects, such as ants, that congregate in colonies underground.

Davis (*ibid.*) has discussed the properties of a number of soil insecticides, including sodium and potassium cyanide, which have been tried by different experimentalists against wireworms and white grubs. The prohibitive cost of these materials and of their application has prevented their general adoption.

5. *Chemical Fertilisers.*—Various authorities, too numerous to mention, have at one time or another advocated the use of chemical fertilisers such as nitrates, sulphates, and phosphates for the control of wireworms and cutworms. It is questionable whether in the quantities that can be economically applied these substances have any appreciable value in stemming an attack. It is generally accepted that they prove beneficial by supplying the growing plants with essential mineral food substances, which stimulate growth and assist in carrying the plants rapidly beyond the young stages, when they are more susceptible to insect injury.

BIBLIOGRAPHY

1. Adams, C. C. (1915), "An Ecological Study of Prairie and Forest Invertebrates," *Bull. Ill. State Lab. Nat. Hist.*, xi, art. ii.
2. Buckle, P. (1921), "A Preliminary Survey of the Soil Fauna of Agricultural Land," *Ann. App. Biol.*, viii, No. 384.
3. Cameron, A. E. (1913), "General Survey of the Insect Fauna of the Soil within a Limited Area near Manchester. A Consideration of the Relationships between Soil Insects and the Physical Conditions of their Habitat," *Journ. Econ. Biol.*, viii, No. 3.
4. Cameron, A. E. (1914), "A Contribution to a Knowledge of the Belladonna Leaf-Miner, *Pegomyia hyoscyami* Panz., its Life-history and Biology," *Ann. App. Biol.*, i, No. 1.
5. Cameron, A. E. (1916), "Some Experiments on the Breeding of the Mangold Fly (*Pegomyia hyoscyami* Panz.) and the Dock Fly (*Pegomyia bicolor* Wied)," *Bull. Ent. Res.*, vii, pt. 1.
6. Cameron, A. E. (1917), "The Insect Association of a Local Environmental Complex in the District of Holmes Chapel, Cheshire," *Trans. Roy. Soc. Edin.*, lii, pt. 1, No. 2.
7. Cameron, A. E. (1917), "The Relation of Soil Insects to Climatic Conditions," *Agric. Gaz. Canada*, iv, No. 8.
8. Cameron, A. E., and Treherne, R. C. (1918), "The Pear Thrips (*Taeniothrips inconsequens* Uzel) and its Control in British Columbia," Bull. No. 15, *Entom. Branch, Dept. Agric. Canada.*
9. Criddle, N. (1918), "The Habits and Control of White Grubs in Manitoba," *Agric. Gaz. Canada*, v, No. 5.
10. Criddle, N., Cameron, A. E., *et alii* (1920), "Locust Control in the Prairie Provinces," *Entom. Branch, Dept. Agric. Canada*, Circ. No. 13.

11. **Davis**, J. J. (1920), "Miscellaneous Soil Insecticide Tests," *Soil Science*, x, No. 1.
12. **Davis**, J. J. (1922), "Common White Grubs," *U.S. Dept. Agric. Farmers' Bulletin*, No. 940.
13. **Diem**, K. (1903), "Untersuchungen über die Bodenfauna in den Alpen," *Jahrb. der St. Gallischen Naturwiss. Gesellsch. f. das Vereinsjahr*, 1901–1902.
14. **Gibson**, A. G. (1915), "Cutworms and their Control," *Entom. Branch, Dept. Agric. Canada*, Bull. No. 15.
15. **Holdaus**, K. (1910), "Die Siebetechnik zum aufsammeln der Terricolfauna (nebst Bemerkungen uber die Oekologie der im Erdboden lebenden Tierwelt)," *Zeit. f. wiss. Insekten-biol.*, vi, Nos. 1–4.
16. **Hyslop**, J. A. (1915), "Wireworms attacking Cereal and Forage Crops," *U.S. Dept. Agric.*, Bull. No. 156.
17. **Miles**, H. E. (1921), "Observations on the Insects of Grasses and their Relation to Cultivated Crops," *Ann. App. Biol.*, viii, Nos. 3 and 4.
18. **Morris**, H. M. (1920), "Observations on the Insect Fauna of Permanent Pasture in Cheshire," *Ann. App. Biol.*, vii, Nos. 2 and 3.
19. **Morris**, H. M. (1922), "The Insect and Other Invertebrate Fauna of Arable Land at Rothamsted," *Ann. App. Biol.*, ix, Nos. 3 and 4.
20. **Morris**, H. M. (1922), "On a Method of Separating Insects and Other Arthrophods from Soil," *Bull. Ent. Res.*, xiii, pt. 2.
21. **Parker**, J. R., **Strand**, A. L., and **Seamans**, H. L., "Pale Western Cutworm (*Porosagrotis orthogonia* Morr.)," *Jour. Agric. Res.*, xxii, No. 6.
22. **Russell**, E. J. (1913), "The Fertility of the Soil," *Cambridge Manuals of Science and Literature.*
23. **Shelford**, V. E. (1912), "Animal Communities in Temperate America," *Geogr. Soc. Chicago*, Bull. No. 5.
24. **Strickland**, E. H. (1916), "The Control of Cutworms in the Prairie Provinces," *Entom. Branch, Dept. Agric. Canada*, Circ. No. 6.
25. **Treherne**, R. C. (1923), "Root Maggots and their Control," Pamphlet No. 32, *Entom. Branch, Dept. Agric. Canada.*
26. **Treherne**, R. C. (1923), "Wireworm Control," Pamphlet No. 33, *Entom. Branch, Dept. Agric. Canada.*
27. **Vestal**, A. G. (1913), "An Associational Study of Illinois Sand Prairie," *Bull. Ill. State Lab. Nat. Hist.*, x, Art. 1.

POPULAR SCIENCE

EDUCATION IN ANCIENT EGYPT

By WARREN R. DAWSON

OUR alphabet consists of twenty-six letters, and the child who places his foot upon the lowest rung of the educational ladder when he begins to learn his A B C doubtless thinks these letters to be quite needlessly numerous. In the written language of ancient Egypt—the hieroglyphs—over three thousand signs are known, and whilst it is true that many of them are very rare, several hundreds were in common use. And whereas all our letters have one value only, namely alphabetic, the Egyptian signs might under various conditions be alphabetic, syllabic, ideographic, or determinative. Moreover, one and the same sign may, in certain circumstances, play any of these rôles, and may in addition have more than one phonetic value; consequently it will readily be understood that the youthful Egyptian, in beginning his career along the noble path of learning, had from the outset far more to assimilate than the modern child before starting on the more complex problems of grammar and syntax.

We are unfortunately without information as to the method by which the Egyptians arranged and taught their enormous syllabary in the earlier periods of Pharaonic history, but a few documents have survived from the later periods which we will examine hereafter.

It is certain that the *fellahin* and most of the working classes in Egypt could not read or write, and they probably received no education at all. An exception must be made in the case of the workmen engaged in engraving and painting inscriptions on the tombs, etc. These men were able to read and write, a fact upon which we have quite definite documentary evidence. The man who could read and write was called a *scribe*, a term which in general corresponds to the mediæval significance of the word *clerk*. We have abundant evidence that the scribe's profession was held to be one of the greatest dignity and importance, as we shall presently see. We know, moreover, that definite schools existed attached to the great temples and to the government departments, where boys were trained in reading, writing, and arithmetic to equip them for their future careers. Whilst it is true that Egyptian learning was severely practical and in general did not extend beyond the every-day requirements of life, nevertheless one cannot help feeling that this aspect of the question has often been exaggerated, and that the moral and æsthetic aspects of education were by no means neglected. On this point we are fortunately well informed, for antiquity has spared to us a considerable quantity of school exercise-books from which we are able to examine the nature of the subjects taught. Before we examine these, however, we must say a word as to the script and the writing materials employed.

The hieroglyphic signs (which, as is well known, represent human beings, mammals, birds, and other animals in various attitudes, plants, natural, and artificial objects of various kinds) were employed chiefly for monumental purposes, and they are to be found sculptured or painted in great detail upon the temples, tombs, and other monuments throughout Egypt. For every-day purposes, and for manuscripts generally, a cursive script was derived from hieroglyphic, and this is known by the somewhat misleading name of *hieratic*. In this script the signs assume a cursive and abbreviated form, and it bears the same relationship to the formal hieroglyphic writing as handwriting with us bears to printed type. It is merely a question of difference in *writing*, the grammar and syntax being identical with that of hieroglyphic inscriptions. Hieratic manuscripts are always written from right to left in ink with a reed-pen. Red ink is used for headings, dates, colophons, and other similar purposes, and in literary compositions red dots, known as verse-points, placed just above the line, divide the text into verses or paragraphs. The writing material was of several kinds: *papyrus*, a kind of paper made of two or more layers of the fibres of the papyrus-plant gummed together with the fibres of the respective layers at right-angles to one another; *tablets* or wooden boards covered with plaster and whitened; *parchments* or leather rolls; and *ostraca*, *i.e.* potsherds or flakes of white limestone. Papyrus was used chiefly for literary works, letters, and generally for documents of an important nature or intended for permanent use. Tablets were used much in the same way as school slates are used to-day; the writing could be washed out and the surface re-whitened and used again; leather rolls are rare, but commonest of all are ostraca. Jottings and memoranda of an ephemeral nature were scribbled on ostraca, which were thrown away after they had served their purpose, and many school exercises were written on ostraca, as papyrus was expensive and too good for such temporary uses. Papyrus was, however, largely used for school-books, when the pupil had attained sufficient progress to embark upon long texts for which ostraca were too small, and as we have already stated, a number of such papyrus rolls has survived. These school-books may be generally characterised as *Miscellanies* or collections of subjects of a most varied character.

Most of these miscellanies consist mainly of collections of model letters, interspersed with literary exercises often cast in epistolary form. In this we see the practical side of Egyptian education, for it was an essential part of a scribe's duties to be able to compose letters relating to the affairs of business and of civil life. The best known documents of this type are the *Papyri Anastasi I–VI*, *Sallier I*, and *Lansing*[1] in the British Museum, the *Papyrus Koller* in Berlin, the *Papyrus No.* 1094 at Bologna, and the *Papyrus No.* 348 at Leiden. In addition to these, others are known, and also some similar but shorter works written upon ostraca. The names of the pupil and his teacher are often introduced into the letters as those of the sender and the addressee. Egyptian letters can be divided into three classes, (i) Superior to Subordinate, (ii) Equal to Equal, (iii) Subordinate to Superior. The three classes can be readily distinguished by the formulæ employed in them. In the first class, the writer issues instructions to his subordinate without any introductory salutations or courtesies and ends the letter with the curt phrase "Now look to it!" In the second class, greetings and good wishes are exchanged, and the letter ends with "good health to you." Finally, in the third class, when the subordinate writes to his superior, the greater part of the letter is filled with elaborate and servile salutations and prayers, and assurances of fidelity, industry, and close attention to all duties. Many specimens are to be found in the papyri just mentioned of letters of all three types. As to the subject-matter of the letters (as distinct from the epistolary formulæ), we have the most varied topics presented to us. Amongst the letters of the first class we find instructions from absent masters to the servants of their estates to feed their cattle, exercise their horses, and attend generally to their affairs. Again, orders are given to make ready for a visit of the Pharaoh or some important member of his staff, or to collect taxes and tribute. Other letters, again, contain instructions to despatch or receive various commodities by river, or to erect and repair monuments. In the second class we have letters that are little more than elaborate and reiterated good wishes, prayers to the gods addressed by the sender for the recipient's welfare; others, again, give news of absent relations and friends or describe the doings of the sender for the entertainment of the recipient. In the third class we find letters sent by officials to their absent lords, reporting on the good condition and prosperity of their estates, not forgetting to mention that this happy state of affairs is due to their own industry and integrity. The subordinate respectfully prays for the health and prosperity of his lord, "assuring him of his best attention at all times." The educational aim of these model letters is nowhere better exemplified than in the passages which contain long lists of commodities, of articles manufactured or unmanufactured, of food-stuffs, plants, birds, fishes, and minerals, many of them of foreign origin, and obviously introduced to enlarge the pupil's vocabulary and to make him familiar with rare and difficult words. A long list of technical terms—the various parts of the chariot and its equipment—occurs in one letter and evidently has the same purpose in view. Many of these model letters were evidently stock copies, for duplicates of them are found in several papyri. Interspersed amongst the letters we find purely literary exercises in which poetical expression and style are aimed at. Such are the hymns to Amen, the god of Thebes, and to Thoth the god of learning, and to other divinities, which occur. Again, we have flowery and eulogistic descriptions of Thebes, Memphis, and other cities, and complimentary addresses to the Sovereign. It is this feature which leads one to the opinion that the scribe's education was not so severely practical as many writers have suggested, but that the purely literary elements of education were appreciated and encouraged. These little pieces appear amongst the model letters without introductory formulæ, but other passages quite as literary are introduced by the usual epistolary phrases and drafted in the form of letters. Amongst such, a very favourite theme was the admonition of the idle scribe. Several of the papyri contain short passages in which warnings and threats to lazy and indolent pupils are propounded, and the master improves the occasion by dilating on the disgrace which bad habits bring upon the esteemed profession of the scribe and exhorts the erring pupil to mend his ways. Thus in the *Papyrus Koller* the lazy scribe is compared to a careless sailor who stands on the prow of his boat heedless of contrary winds and dangerous currents, and who courts disaster by his negligence. Another similar passage holds up to contempt the scribe who is sowing his wild oats, and pursuing habits of drunkenness and vice. He is stigmatised as being "like a boat that has lost its rudder, like a shrine without its god, like a household without bread," and as being shunned by decent people. A similar passage in the *Papyrus Sallier No. I*, of which several duplicates are known, exhorts the idle scribe to consider the dignified profession to which he belongs and the prospects which his lazy habits are endangering, and draws a lurid comparison between the honourable life of the scribe and the terrible hardships of the field-labourer, who toils from morning till night to raise a poor crop, which is so denuded by vermin and by thieves that he cannot pay his taxes, and is seized, beaten, and thrown in prison. This comparison of the scribe's profession with other callings was perhaps the most favourite of all literary *motifs*. Again and again in the model letters the advantages of the literary career are shown against the lurid background of other callings. The soldier complains that he has too many officers, that he is overworked and badly fed, that he has hardships and feats of endurance to perform which tax him to the uttermost. The charioteer's life is no better, and the manual labourer's life is scarcely worth living. The greater part of the *Papyrus Lansing* is concerned with this topic, and the whole of another literary work known to scholars as the *Satire des Métiers* is devoted to a description of the hardships of workers and craftsmen of various kinds. A complete copy of this work is found in the *Papyrus Sallier No. II*, another copy is contained in *Papyrus Anastasi VII*, and innumerable copies of parts of the text are found on ostraca. This work, from the numbers of duplicates known, must have been the most popular of all literary pieces in the Theban schools under the Ramesside kings. The author admonishes his pupil to pay attention to learning and to uphold the dignity of the scribe's profession, for " I have never seen a smith sent on an embassy, nor a smelter sent on a mission, but I *have* seen the metal-worker at his toil, at his furnace and his forge, his fingers as rough as crocodile-skin and stinking more than fish-spawn." The long text recounts the toils and sufferings of the stone-mason, the barber, the boatman, the field-labourer, the builder, the gardener, the weaver, the dyer, and a host of others.

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[1] I have given an account of this newly-published papyrus in the *Asiatic Review*, April 1925, pp. 309 ff.

We owe to the youthful scribes and schoolboys of Egypt a number of ancient literary works, the originals of which are lost, but which have survived wholly or partly in school copies. The celebrated *Story of the Two Brothers* has come down to us in the copy made by the schoolboy Ennene, who lived in the reign of Sety II (about 1205 B.C.), and to whom we are indebted for the *Papyrus Sallier No. II*, which contains three literary works, and the *Papyri Anastasi IV* and *VI*, which are collections of model letters. Another youthful scribe, Pentowere, who was educated in the reign of the Pharaoh Meneptah, successor to Ramesses the Great, has left us two of his school books, known to-day as the papyri *Sallier I* and *Sallier III*. The first of these opens with an historical romance in which the Theban king Sekenenre quarrels with the Hyksos ruler Apophis; unfortunately Pentowere did not finish the story, but broke off in the middle of a sentence, probably when dismissed from school, to resume with "the beginning of the manual of letter-writing made by the scribe Pentowere in the year 10, seventh day of the month of Hathor" (November 16). The other papyrus contains a copy of the poetical account of the victory of Ramesses II over the Hittites which the king won in the fifth year of his reign.

Another literary classic which was very popular in the Theban schools of the new kingdom is a book entitled "The Instruction of Amenemmes to his Son." This Amenemmes was a celebrated Pharaoh, the founder of the Twelfth Dynasty (about 2000 B.C.), who made a kind of political testament confiding a prosperous and pacified kingdom to his son's charge. No contemporary copy of this book has survived, and we are therefore indebted to the pupils Pentowere, Ennene, and others who have left us their school copies made several centuries later. The same may be said of several other Egyptian literary works. Incidentally it may be noted that these literary classics must have been very limited in number, for in almost every instance duplicate texts have been found. The most notable exceptions to this statement are afforded by the stories of the magicians of the Pyramid Age preserved in the *Westcar Papyrus* at Berlin, and the *Story of the Two Brothers*, mentioned above, each of which is known to us from a single manuscript.

Mathematical exercises have been found, but are not common. The *Rhind Mathematical Papyrus*, which is a large document containing tables, calculations, and geometrical problems, is the principal source of our knowledge of Egyptian mathematics, and this supplemented by a number of lesser fragments. An account of this papyrus and of Egyptian mathematics in general by the present writer appeared in SCIENCE PROGRESS, July 1924, Vol. XIX, pp. 50–9. For the ancient Egyptian, mathematics was a science entirely for practical purposes, and having attained its purpose, tended to stagnate; but as I have shown elsewhere, the Egyptians had very considerable knowledge of mathematics and were capable of making abstruse calculations. Ostraca covered with figures are frequently found, but little can be learned from these detached fragments. In the writer's collection is an ostracon on one side of which is an extract from a literary work, a full copy of which is preserved in a papyrus which is now in Russia, and on the other side is an exercise in numbers, the numerals from 1 to 70,000 being written in their hieratic forms in units, tens, hundreds, etc. Arithmetic, and especially weights and measures, play a prominent part in the papyri and ostraca containing accounts of which innumerable specimens have been found.

With regard to Egyptian lesson-books in general, it may be said that most of the texts so preserved to us are very corrupt, and contain all the offences against grammar and spelling which the schoolboy has kept as a living tradition throughout the ages. Corrections by the teacher's hand are often to be seen in the margins, and it was customary for the pupil to write the date in red ink at the termination of each day's lesson. The writing is, generally speaking, very good. The pupil was required, naturally, to write his exercises in his very best handwriting, and consequently the school-books are easy to read, far easier than the very cursive and ligatured writing of the professional scribes, as we see in the many juristic and business documents which have survived. The writing of actual letters (that is to say real letters missive, as opposed to the model letters described above) is often extremely difficult to decipher. In idle moments the schoolboy frequently drew pictures of animals, etc., in the margins of his book, and indulged in aimless scribblings.

The tuition in Egypt seems to have been carried out by professional scribes in various administrative offices to juniors whose status must have been very like that of apprentices. In the temple-schools the teaching was done by priests. We have no information as to the details of the schools, but from many indications we may gather that discipline was strict, and was rigidly enforced. We may merely quote a sentence in the *Papyrus Anastasi III* in support of this view : " A boy's ears are on his back ; he hears when he is beaten," says the teacher.

The papyri described above and the comments we have made thereon refer to the period of the Eighteenth–Twentieth Dynasties. When we come to later times we have some scraps of evidence of another kind to consider, but before going on to these we may mention in passing that books of reference were compiled, doubtless for educational purposes, and these include vocabularies, or classified lists of words. The most important of these glossaries have not yet been published, so that in the meantime we may merely note their existence.

In the spring of 1884, whilst exploring the ruins of the city of Tanis in the Delta (the Sân of the Old Testament) Sir Flinders Petrie found the charred remains of a batch of papyri in the debris of a house that had been burnt. Amongst these charred remains was one papyrus of quite exceptional interest, and with almost incredible patience and skill Prof. Griffith pieced the blackened fragments together and deciphered them, the results of his labour being published by the Egypt Exploration Society in a special memoir. The papyrus is of late date (Greco-Roman) and contains a list of well-drawn hieroglyphs, with an explanation written in hieratic against each sign. It is the first and only native list of hieroglyphs which has come down to us. The first sign is the bee, a royal emblem, and it is followed by a number of signs representing human beings in various attitudes. These are succeeded by the frog, fishes, reptiles, and various other animals. For a space the classification is not so definite, but it is resumed in a series of parts of the human body and parts of animals. The sky, sun, and moon follow next, then the earth, after which classification ceases and the remaining signs are presented in quite arbitrary order. The two first columns, namely the hieroglyphs and their hieratic equivalents, have an obvious educational value, and the notes in the third column, which give either the phonetic value or meaning, is doubtless intended to convey the names by which the signs were generally known or might be recognised. Professor Griffith in commenting on the papyrus says "the need must have been felt in Egypt for some means of distinguishing hieroglyphic signs *viva voce*, both in the schools and in ordinary life. Names must therefore have been attached to the immense hieroglyphic syllabary, and taught with care, from the earliest times. If we consider the third column as devoted to the names of the signs, we shall find a fair explanation" (*Two Hieroglyphic Papyri from Tanis*, p. 5).

After the Twenty-sixth Dynasty (about 650 B.C.) hieratic writing gradually gave place to a later and still more cursive script known as *demotic*, and in Ptolemaic times demotic was used almost exclusively for all but religious purposes. We have, however, no demotic school papyri corresponding to those described above—the hieratic papyri of the Eighteenth–Twentieth Dynasties, but a few ostraca have survived which are of extreme interest in the history of education. These ostraca, several of which are known, are inscribed with paradigms and are actual lessons in the conjugation of verbs. To those already known another has been added and recently published (N. Reich, *Journal of Egyptian Archæology*, vol. x, p. 285), and conjugates the past tense of the verb "to say." The order is the same as that which we should use in a modern grammar-book, *i.e.* 1st person; 2nd person, masculine and feminine; 3rd person, masculine and feminine: and similarly for the plural.

"*Singular.* I said.
Thou saidst (masc.).
Thou saidst (fem.).
He said.
She said.

Plural. We said.
Ye said.
They said."

When Christianity was introduced into Egypt, demotic writing finally gave place to *Coptic.* The Coptic language is the ancient language of the hieroglyphs (greatly modified of course by the lapse of time, just as modern Italian differs from classical Latin), written in Greek characters, but with six additional letters borrowed from demotic to represent sounds not known in Greek. The Coptic Christians often took possession of the great tomb-chambers of earlier ages and occupied them as houses, churches, and schools. The famous tombs of Beni Hasan which date from the Twelfth Dynasty were so occupied, as many Coptic *graffiti* on the walls prove, and in one of them, Tomb No. 12, is a most interesting Coptic inscription which is a spelling lesson. The original, a reduced facsimile of which is here reproduced, is roughly and irregularly traced, and is partly effaced, but it is easy to restore the missing parts of the columns.

In the first register are three columns, the first of which contains the Greek alphabet (written with the characteristic Coptic forms of the letters) in its normal sequence. In the second column is the same alphabet written backwards, and in the third it is written in an arbitrary order thus : the first letter and the last, then the second letter and the penultimate, and so on ; but with an error, for *Σ* is out of place, which upsets the true order. These three columns are evidently for teaching the alphabet, for the pupil had to know each letter, and to be able to recognise each in its normal order, then backwards, and finally in a promiscuous order.

The second register and the first eight columns of the third are occupied by simple two-letter syllables each composed of a consonant and a vowel. Each consonant is combined with each vowel in turn, but again an error has occurred, for the positions of κ[1] and ρ are transposed.

The remainder of the third register, and cols. 1–7 of the fourth, sets out another series of combinations. Here we have three-letter syllables, all beginning with β and ending with the consonants in order from β to ξ. Thus the series is incomplete, as the final consonants from π to ψ are wanting. The column ending in ζ is out of order, being placed, as it is, between γ and δ. The next series, which extends from the eighth column of the fourth register to the fifth column of the last register, is a similar set of compounds beginning with γ, which is in correct order following the series with β. All the consonants are used in this group; but as usual, with errors, for the final χ, φ, τ, and ψ are in wrong order. Another series

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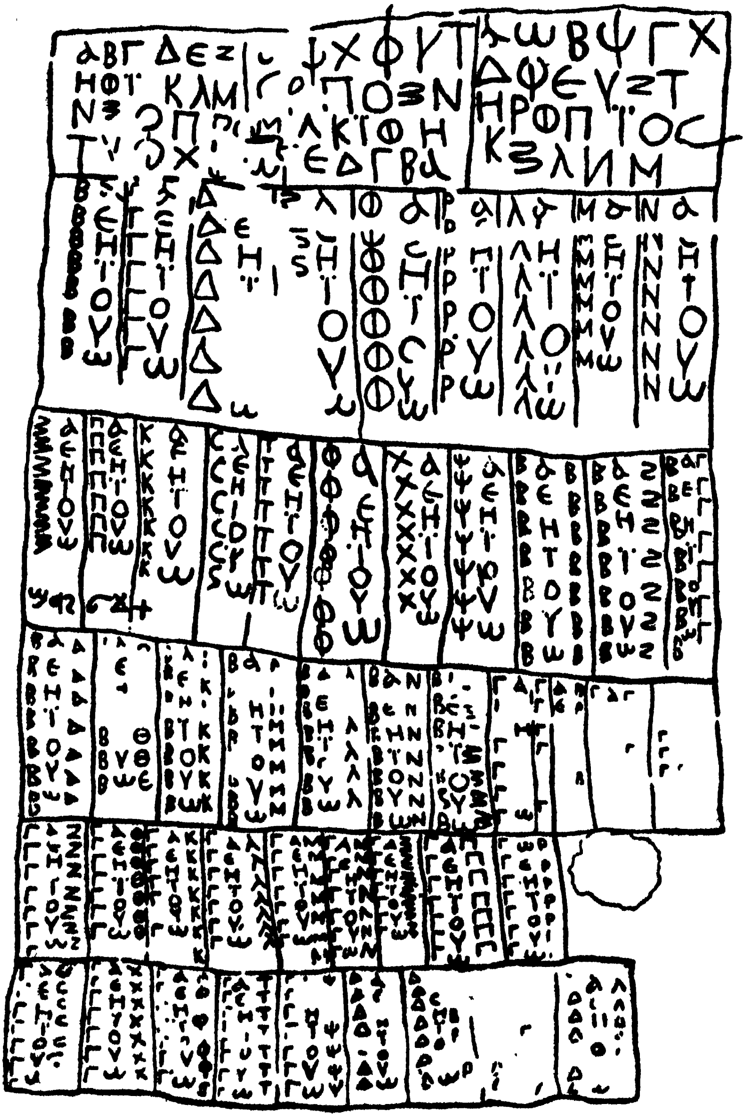
[1] In these paragraphs the Greek type equivalents are used for the Coptic forms on the original, as being more easily understood.



of the same type, beginning with δ, was commenced in the last three columns of the lowest register, but this comes to a premature end through lack of space after the group δαδ. It may be noted that the last two series, γαβ and δαβ, are preceded by the simple combinations *γα* and *δα*, but the first series *βαβ* omits this introductory column.

This table is of the greatest interest, for it shows a method of teaching exactly similar to our g-o = " go," c-a-t = " cat." The table is full of mistakes, some of which we have pointed out, and to these we may add that *θ* in cols. 1, 2, 3, and 8 is written ⊖; in col. 3 *N* is written backwards; in the last column of the fifth register *γωρ* is written in the first line instead of *γαρ*; and finally in the fourth register the ruling cuts the syllable *γαγ* after the second letter, to remedy which another line was traced to divide the column from the one in front of it, which has two letters only.

We may also note that the six Coptic letters, which are not employed at all in the table, are written at the foot of cols. 1–3 of the third register.

From the above remarks it must be admitted that from material at present available we can do no more than indicate some general facts regarding education in Egypt. Perhaps future discoveries may enlighten us as to the exact manner in which the alphabet, syllabary, and grammar were taught in ancient times. Although unknown to us, a method, and a very efficient one, must have been devised and used, otherwise the innumerable hieroglyphic, hieratic, and demotic texts now available to scholars could never have been written.

NOTES

Government and Research

The Government Estimates for this year provide the sum of no less than £4,045,000 for "scientific research." This figure is surprising ; but, so far as can be ascertained, half the sum will go to the principal Departments of State for technical investigations connected with ships of war, aeroplanes, artillery and so on, while much of the remainder will fall to the "Research Boards" concerned with such subjects as building-material, forestry, fuel, engineering, and geology, and to the National Physical Laboratory, to agriculture, and to the office of Works, for similar studies. It is to be doubted whether much more than one-tenth of the total sum is spent upon "pure science," even if we include medical and veterinary investigations under this heading. Researches on aeroplanes, guns, crops, cattle, and so on are very important, but can scarcely be classed with those aimed at discovering the general laws of nature concerned with matter, force, life, and disease—even though the latter studies often prove to be practically useful. What proportion of the large total sum ever yields much fruit remains doubtful.

The Industrial Institute

We have received the following prospectus regarding this movement :

The Industrial Institute represents no partisan interest ; it has no axe to grind. Its programme is comprehensive and far-reaching. It is believed that no other organisation has attempted to cover the same ground. It affords opportunities for men and women of every variety of outlook to meet and consider how every kind of question, touching industry and its bearings on life, may be dealt with in the national interest. It is not concerned to maintain private ownership, nor to develop public ownership, but simply to study things as they are, and to organise an approach in the mood, and by the method, of Science towards those fundamental problems of industry which tend to divide men into opposing camps to the detriment of the nation and of every individual.

It embraces men and women of position in Science and Statecraft, in Religion, Ethics, and the Arts, as well as those responsible for affairs in Manufacture, Distribution, and Finance.

The moral support of the leaders of the scientific world, including the heads of the Universities, is of immeasurable value, since it establishes beyond all question that the Institute is a scientific and not a political nor a propaganda body. Their presence will, further, guarantee that the Institute will maintain that position.

Within the term " Industry " it includes not only the making of commodities but the marketing of them, and also the financing of both those interdependent processes. It includes, also, the industries of agriculture and fishery.

It believes that the one effective bond of union between conflicting interests which will stand the strain of controversy is to be found in the desire for knowledge ; and it is hoped that association in the pursuit of knowledge may tend to unite in sympathy and in mutual understanding those who take part in it.

It proposes to develop the science of descriptive economics, to unravel present-day tendencies, and to strengthen the foundations of industrial ethics.

It assumes that industry is made for man, and not man for industry. It conceives that the object of human life is the development of freedom and happiness. It believes that happiness is to be found in the enjoyment of the good, the true, and the beautiful.

It believes that among the multitude of present-day problems the most pressing is the relief of unemployment, and the stabilisation of employment.

It proposes to begin, and to follow up, its work along four main paths, namely : (i) the study of the possibilities of industrial development throughout the Empire ; (ii) the investigation of the problem of an industrial development which shall be so adjusted and balanced that the irregularities of trade may be reduced ; (iii) the formulation of the fundamental problems of industry with a view to the promotion of national clearness of thinking ; (iv) and inquiries into such specific questions of detail and of fact as it may find means to prosecute.

It believes that the longer anyone considers its possible scope the larger will become the view as to its probable usefulness.

The ideal is to form within the Institute a body of persons so knowledgeable, and of so varied an experience in industrial and other affairs, that, collectively, they can obtain access to every source of information, and create a body of knowledge so exact, and so widely based, that neither industry as a whole, nor any section of it, nor any Government will be able to afford to reach conclusions without reference to it for information and for the use of its collective experience.

The Institute has now over 230 members, every one being a representative and responsible person. The work of the first year, just concluded, has, mostly, consisted in securing the interest of those members. Their names show a widespread belief that useful work can be done on the lines suggested. The time has come when steps must be taken to raise the necessary funds to enable the scheme to be tried out. A trial period of not less than four years should be provided, to give the plan a fair chance, and to carry out the ideal of those who founded the Institute. The movement has been carried to this point with a total expenditure of the sum of £357 17*s.* 7*d.*

The Practical Application of the Sciences

In *The Times* of May last Lord Raleigh says that "Scientific investigations of obscure phenomena have not, as a matter of history, been made from utilitarian motives at all, but from motives of intellectual curiosity." We have often contested this point in SCIENCE PROGRESS. Surely the history of science shows that much investigation has been promoted by utilitarian purposes. We may mention almost the whole of medical science, which is aimed at the very utilitarian purposes of preventing or curing disease. Early geometry was, we are told, created in the interests of architecture, and trigonometry in the interests of navigation. Surely also a very large part of chemistry is now being studied in the interests of manufactures and for other practical purposes. Astronomy and physics are perhaps above, or below, utilitarian motives ; but one never knows when advances in any one science may not prove to be practically useful to the human race—as, for instance, in the case of electricity ; and we believe that workers in these lines frequently have a subconscious feeling at least that their work may confer some practical benefit on mankind in the future. There is nothing dishonourable in utilitarianism.

The Flare-phenomenon in Smallpox (R. R.)

Some years ago I wrote a note in *The British Medical Journal* on what I called "The Flare-phenomenon" in epidemics, derived from a mathematical study of epidemics in general. By this phrase I meant the sudden upward rise of the bell-shaped curve which is given by the daily records of new cases in nearly all epidemics, a curve which is derived from the integration of the differential equation constructed by me (*Proceedings, Royal Society*, 1916, 1917). No notice was taken of these papers in this country (though the Americans are working at the subject); but the steady increase of smallpox in Britain, owing to the neglect of vaccination during the last few years, is now threatening a "flare-phenomenon" of this horrible disease among us. If it occurs, it will be solely the cranks and the politicians who will be to blame.

Medical Councils

In *The Times* of May 22 Prof. Sir W. J. Simpson, M.D., writes: "In reading in *The Times* the names of the members of the Conference on Sleeping Sickness now being held in London, it has surprised me, and must have surprised many others, to notice that the group of distinguished men who elucidated the etiology and the mode of spread of this terrible scourge are not mentioned." Our more civilised neighbours across the Channel place the portrait of Pasteur on some of their postage-stamps: imagine the English doing anything of the kind! On the contrary, it seems to be a principle of administrations with us even to exclude as much as possible from our medical councils the very men whose researches created any given branch of knowledge, while other people are frequently allowed to swarm in and direct the disposal of the scanty funds which we allow for such purposes. One wonders how much public money has been wasted in this way.

The Religion of a Darwinist (R. R.)

Everything written by Sir Arthur Keith, F.R.S., is welcomed both for its wisdom and for its style. His Conway Memorial Lecture with the above title delivered at South Place Institute on March 26, 1925, with the Rt. Hon. J. M. Robertson in the chair, is no exception to Sir Arthur's usual contributions to thought, and has been printed in a small volume by Watts & Co., Fleet Street, E.C.4. The chairman began very wisely by showing that the word *religion* may imply the scientific conclusions of a writer rather than any definite system of so-called belief, at least those held by most people. Sir Arthur says that "somewhere between the basement and the attics of that home in which we lead our mental lives there is an apartment which most men and women keep under lock and key." It is there that he has evidently kept a "private still" in which he has for many years been secretly fermenting a certain strong drink of thought, ultimately maturing it into a perfect wine of wisdom. Everything in the lecture is most delicately put. "The Darwinist's bible is the great book of nature. Creeds will come and go, but this is the book which will endure as long as life lasts," he says. "Man has climbed up the ladder of civilisation, but it is the same old body and the same old brain which he has dragged with him. Every one of us is the descendant of a member of a hunting pack. Our bodies and minds were evolved in the environment of hunting and fighting during an uncountable number of generations. Our brains are equipped for such a manner of living. It was then that the inner sanctuary of our mental lives ran riot with the hobgoblins of superstition." "There has been progress; a truly rapid and marvellous progress it has been, but we have brought with us the old brains and the old heart from primitive times Every child is still born a savage;

his task in life is to climb the ladder of civilisation." To this perhaps may be added the dictum of Meredith, that the last thing to be civilised by men will be women! Perhaps, however, it may be more truly said that the last thing to be civilised by men like Keith will be the vast masses of the men who are unlike him.

Spurious Evidence

In *The Times* of January 2, 1925, Mr. A. A. Campbell Swinton, M.I.C.E., F.R.S., contributes a very interesting letter on the subjects of "N"-rays and of the acceptance of spurious evidence even by men of scientific distinction. This letter has a close bearing on numerous articles which appear in the lay press, in which such gentlemen still seem often to accept almost anything that is told them.

Sir,—Before the interesting, but, I fear, necessarily inconclusive, correspondence on the value of evidence in telepathy and suchlike phenomena closes, may I draw attention to the strange story of the "N"-rays—a story which in its entirety is little known, but, as it seems to me, is most instructive, in showing how little reliance can be placed upon evidence in regard to phenomena which can only be perceived by certain individuals and not always even by them, evidence, however, put forward, confirmed, and accepted by experts of the highest repute, whose *bona fides* is beyond question?

It was some twenty years ago, a few years after Röntgen's discovery in Germany of the X-rays, and Becquerel's discovery in France of radio-activity, that one of the most curious episodes in the history of modern science took place in France. Professor Blondlot, a well-known professor of physics in Nancy, who had done excellent work in other directions, announced that he had discovered another, and new, description of radiation, which he named the "N"-rays. With these rays, which he stated were emitted by nearly all bodies in a state of strain, he claimed that he could see in the dark, and with them he even professed to be able to produce a line spectrum. Sir William Crookes, Lord Rayleigh, and others in this country tried to repeat Blondlot's experiments, but no one had any real success. I can well remember my own exceeding disappointment at my failure to obtain the slightest result after prolonged and strenuous endeavours. Sir William Crookes even went out to Nancy specially to see the rays. He was shown a spectrum which was produced by a prism, and was told that if he would turn a handle connected with the prism, so as to cause the latter to rotate, he would see the spectrum and its lines move. As a matter of fact he saw neither spectrum, nor lines, nor anything at all. He did not turn the handle, but made a pretence of so doing, whereupon the other observers pointed out to him how the spectrum and the lines were moving. Sir William Crookes came back from France quite unconvinced of the existence of these wonderful rays, but he was too polite to publish any account of his experiences. In France, however, a number of distinguished French men of science continued to believe in them, so much so that the Académie des Sciences—a body that corresponds to our Royal Society—solemnly presented Professor Blondlot with a gold medal for his discovery.

Then came the *dénouement*, when Professor R. W. Wood, Professor of Physics at the Johns Hopkins University, Baltimore, a very well known physicist, and now a foreign member of the Royal Society, came on a visit to Europe, and thought he would like to see these remarkable rays. I have the sequel from Professor Wood himself. He went to France, and, like Crookes, was shown the spectrum of the "N"-rays produced by means of a prism. Professor Wood himself, again like Crookes, could see nothing, but the French scientists, assembled at the gathering, saw, or, at any rate, professed to see, the spectrum, and the remarkable thing was that they continued to see it even after Professor Wood, taking advantage of the complete darkness in which the experiments were being shown, had surreptitiously removed the prism out of the apparatus and put it in his pocket.

Nowadays one never hears of the "N"-rays, and I do not think that they are even mentioned in any modern scientific book. Professor Wood, by his perhaps rather venturesome action, gave them their quietus. Probably the phenomena were due to some peculiar form of self-hypnotism. It must, however, have been mass self-hypnotism, as many were successful. No doubt the observers were perfectly genuine, but what they saw, or thought they saw, was subjective and not objective.

Now, all modern physical science is built upon experimental results which any normal individual, employing the necessary apparatus, is able to confirm for himself. All other results must be subject to a certain amount of legitimate suspicion, and the story of the "N"-rays shows how even the highest authorities can be deluded into believing in phenomena which have no real objective existence.

Yours faithfully,
A. A. CAMPBELL SWINTON, M.I.C.E.

WESTMINSTER,
December 29.

Forms of Equilibrium of Fluid Masses under Tidal Stress (W. E. Crowther, [illegible].)

A body of fluid under the attraction of another mass must assume an elongated form, because one side is nearer to the attracting mass than the other and is therefore subject to a stronger distortional stress.

Though distorted, the volume of the body remains constant; the girth therefore decreases, all longitudinal sections becoming oblongs with curvilinear perimeters.

Since the ellipses are the only curvilinear oblongs which have constant relations between their areas and the products of their major and minor axes, the sections must be ellipses and the body an ellipsoid.

The following physical considerations confirm the foregoing.

Elongation of the mass is accompanied by a primary tendency to heap the frontal waters and produce an ovoid form. The effect is enhanced by the fact that at the rear attraction assists gravitation and tends to flatten the spherical surface. Consequently, a tendency to displace the centre of gravity inwards towards the source of attraction arises, but this point being restrained to its course or orbit, the mass itself will shift outwards until balanced about the centre of gravity.

We must now consider whether the ovoid will retain its form under the stresses mentioned.

If from the centre a pair of radii be taken towards the ends at the same angle with the axis, as representing lines of force, it will be seen that one acts on the surface particles at a greater advantage than the other, and that fluid will, therefore, be translated from the broader to the narrow end, until equality of volume and similarity of contour be reached.

Further and alternatively, if the mass be imagined to consist of an infinite number of parallel plane ovals, it will be seen that their centres of gravity do not lie in a straight line. This condition cannot persist because the points attract each other and become a straight transverse line containing the centre of gravity of the mass. The result is that the front narrower surface is rounded outwards and the back surface retracted into conformity.

Notes and News

The annual elections of officers of the chief scientific societies have resulted in the following presidential appointments :

Royal Astronomical Society	Dr. J. H. Jeans.
Royal Microscopical Society	Mr. A. Chaston Chapman.
Chemical Society	Dr. A. W. Crossley.
Institute of Chemistry	Prof. G. G. Henderson.
Geological Society	Dr. J. W. Evans.
Meteorological Society	Mr. C. J. P. Cave.
Institute of Mining and Metallurgy	Sir Thomas H. Holland.
Institution of Petroleum Technologists	Sir Thomas H. Holland.
Physical Society	Mr. F. E. Smith.
Optical Society	Mr. T. Smith.
Ray Society	Prof. W. C. M'Intosh.

The Faraday Medal of the Institution of Electrical Engineers has been awarded to Sir J. J. Thomson.

Dr. J. H. Jeans and Sir W. H. Ellis have been appointed members of the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research.

Sir John E. Russell, Director of the Rothampsted Experimental Station, has been elected a corresponding member of the Paris Academy of Sciences.

The Prince of Wales has consented to act as President of the British Association for the meeting at Oxford in 1926. The meeting will be held during the last week in July or the first week in August. The meeting this year at Southampton takes place from August 26–September 2, Dr. Horace Lamb being President.

Our obituary list this quarter is exceptionally long, and contains the names of many whose passing over leaves very conspicuous gaps in the ranks of science workers. It includes Sir Thomas Clifford Allbutt, Regius Professor of Physic in the University of Cambridge ; Mr. W. W. Rouse-Ball, mathematician ; Dr. W. Borchers, Professor of Metallurgy at the Technical Institute, Aix-la-Chapelle ; Dr. J. Cleland, F.R.S., Emeritus Professor of Anatomy in the University of Glasgow ; Sir A. Critchett, ophthalmologist ; Prof. A. Dendy, zoologist ; Sir Rickman Godlee, surgeon ; Prof. W. A. Haswell, F.R.S., Emeritus Professor of Biology in the University of Sydney ; Oliver Heaviside ; Dr. W. F. Hillebrand, Chief Chemist of the U.S. Bureau of Standards ; Prof. W. H. Julius, physicist of the University of Utrecht ; Dr. E. E. Klein, F.R.S., bacteriologist ; Dr. N. Kulchitsky, histologist ; Dr. W. McInnes, formerly Director of the Geological Survey of Canada ; Sir William Peck, Director of Edinburgh Observatory ; Mr. T. H. Powell, microscopist ; Sir David Salomons, electrical engineer ; Sir T. Edward Thorpe, chemist ; Prof. A. von Wassermann, pathologist; Mr. W. Watson, lately Curator of the Royal Botanic Gardens, Kew; Mr. C. H. Wordingham, past President of the Institution of Electrical Engineers.

Recently the Royal Society proposed to sell or to exchange a number of old books, not directly connected with science, which were presented to it on January 2, 1666–7, by Mr. Henry Howard " with the library of Arundel House, to dispose thereof as their property." Discussion on this proposal has occurred in *The Times* recently (see April 30), and it has been argued that the word " dispose " then meant " to place or arrange," and not " to sell or get rid of," as it does most commonly to-day. The apartments of the Society at Burlington House are so small and its subsidy received from the nation so niggardly—considering its importance—that we are glad it finds itself free to do as it pleases in the matter. Many academies of science pay their members; ours is so poorly treated that it is obliged to obtain subscriptions from its fellows—the British have an antediluvian way of looking at all scientific matters. The Society exists to augment " natural knowledge," not to collect old books; and we are glad that it raised £14,749 by the sale of those referred to.

The Trustees of the Captain Scott Memorial Fund have given £13,000 to the University of Cambridge for the use of the Polar Research Institute recently established at that University. It is hoped by its founders that this Institute will become a depository for the records and equipment of polar expeditions, and a centre for the collection of data and experience which might be helpful to future expeditions. The funds at the disposal of the Institute are entirely insufficient to enable it to be responsible for any direct exploration.

The second session of the Summer School for Post-graduate Mathematics, organised by the Extra-mural Department of the University of Manchester, will be held at University College, Bangor, from Monday, August 24, to Saturday, September 5. The object of the school is to afford facilities for advanced study in mathematics to teachers and others who have read mathematics for a university degree. The following three alternative courses are proposed, each one consisting of twenty lectures of one hour each, two lectures being taken on each of ten mornings:

Atomic Structure and the Quantum Theory, by Prof. Sydney Chapman, M.A., D.Sc., F.R.S.; Theory of Functions, by Prof. L. J. Mordell, F.R.S.; Higher Geometry, by Mr. H. W. Richmond, M.A., F.R.S.

Details of the fees, hostel accommodation and syllabuses may be obtained from Miss D. Withington, The University, Manchester.

A most successful meeting of the International Geographical Congress took place at Alexandria and Cairo during the period March 28–April 9. The British delegation was headed by Sir Francis Younghusband. On the evening of March 28 King Fuad received the congress at his palace, and on April 3 the Jubilee of the Royal Geographical Society of Egypt was celebrated by the delegates. The next meeting will be held in England in 1928.

The Pasteur "badge" day organised in France in May 1923, as part of the Pasteur centenary celebrations in aid of scientific work, yielded 9,000,000 francs, and an additional 3,000,000 was subscribed to a fund managed by the *Matin.* This latter sum has been invested and the interest will be used for prizes and grants for scientific work. The main fund has been distributed by a Committee of which M. Émile Picard, permanent secretary of the Paris Academy of Sciences, was chairman. Rather more than 2,000,000 francs is allotted to physics, 1,000,000 being ear-marked for the construction of a large electromagnet for the Paris Academy; 1·3 million is given to chemistry and 1·1 to astronomy, the remainder being distributed among the other sciences.

The organisation of a "flag" day in aid of the scientific laboratories indicates that the interest in science in France is more widespread and more practical than in this country. That the interest is most probably in the success of French science does not lessen its usefulness as an example to the rest of the world. This interest is indicated also by the publication of two most imposing volumes entitled, *Histoire des Sciences en France*, being volumes xiv and xv of a *Histoire de la Nation Française*, edited by Gabriel Hanotaux of the Académie Française. (Published by Plon-Nourrit et Cie, 8 rue Garancière, Paris, for the Société de l'Histoire Nationale.) Each of these volumes contains over 600 quarto pages, and is plentifully illustrated by woodcuts of old prints and by coloured plates (these mostly rather trivial). The first of the two volumes deals with the physical sciences, the second with biology and philosophy. Schuster and Shipley, in their book, *Britain's Heritage of Science*, attempted something on this plan for English science just after the war, but the means at their disposal were inadequate for an undertaking on the scale of the volumes under review. That would be a possible and worthy task for the Royal Society to put in train. A most pleasant feature of this French history is the constant reference to the work of men of other nationalities which has touched upon or rendered possible the achievements of France.

In a letter to *Nature* (April 18), Prof. Michelson and Prof. Gale gave brief details of results they had just obtained from a new interference experiment designed to test once more whether the æther near the earth's surface is at rest, or in motion relative to that surface. A beam of monochromatic light was split into two parts, one of which travelled clockwise, and the other counter-clockwise round a rectangular path 2,010 by 1,113 ft. Since experiments in the open air on this scale are impossible, on account of the effects of atmospheric disturbances, the light was passed through a 12-in. water-pipe containing air maintained at a pressure of ½ in. of mercury by a 50 horse-power pump. The result showed that the beam travelling counter-clockwise was retarded behind the other by 0·230 of a fringe. The theoretical value on the assumption of a *stagnant* æther is 0·236 of a fringe in the latitude in which the experiment was performed.

The conclusions drawn from the famous experiments of Michelson and Morley were just the reverse of this, the results indicating that the æther near the earth travels with it. Comments on the new results are, as yet, very few. Letters from Larmor and Jeans appeared in *Nature* for May 2. Prof. Larmor considered the result inevitable if the atoms of matter subsist in a universal medium as independent small structures, and regrets that the uncertainty in the result is twelve times too great to provide an independent means for the determination of the aberration constant. Dr. Jeans pointed out that the experiment indicates that the velocity of light is the same to 1 part in 10″ whether the light is travelling in the direction of the earth's rotation, or in a contrary direction. This result he claims to be in accordance with the relativity principle. He considers the experiment to prove the absence of an æther moving with the earth and to leave open the question of the existence or non-existence of a stagnant æther.

The controversy between Prof. McLennan and Prof. Vegard regarding the origin of the green line in the spectrum of the aurora has been carried a stage further by two communications from McLennan to *Nature* (March 14 and April 25). In the first, a cable, it was stated that a line had been observed in the spectrum of a mixture of air and helium (the latter being in excess) at 5577 ± 0·15, which was considered to be identical with the green auroral line. A mixture of oxygen and helium showed the same line, but brighter. It was not observed with pure oxygen, nitrogen, hydrogen or helium, and in no other combination of two of these gases. A long discharge tube partly immersed in liquid air was used for the experiments, the best results being obtained at a pressure of 5 mm. of mercury. The second communication took the form of a letter signed by Prof. McLennan and Dr. Shrum, in which it was stated that the line could be obtained at room temperature under suitable conditions of pressure and that it probably has its origin in oxygen.

The British Non-ferrous Metals Research Association has issued a Report containing an admirably clear account of the researches in progress, or completed, designed to assist the commercial work of the members of the Association. Several of the researches deal with copper and brass, others with aluminium, zinc, lead, and nickel. The engineering industries will doubtless be attracted by the study of the prevention of wastage of locomotive fire-box stays and the search for alloys suitable for high temperature service and the work on die-casting alloys.

The investigations on the soldering and brazing of metals and on atmospheric tarnishing and corrosion should interest even wider circles, particularly the building industries, and even the eventual public or private user of metal construction and appliances.

The Association has already obtained such support from the industry, increased *pro rata* by a grant from the government Research Department, as to be able to expend this year £16,000 on these researches. Now that it is firmly established, it is anxious gradually to become self-supporting by an accession of new members from the non-ferrous industry itself, and from the engineering and other users who stand to benefit by the results of its labours.

Mr. Murray has published two more of the monographs on the Mineral Resources of the World, prepared by the Imperial Institute. This time the metals dealt with are Bismuth (by Robert Allen, M.A., B.Sc. Price 3*s.* 6*d.* net), and Antimony (by Edward Halse, A.R.S.M. Price 5*s.* net). In the first of these two monographs it is stated that, in pre-war days, most of the bismuth compounds required for industrial purposes were prepared at Schneeberg in Saxony, but that since then nearly all the Bolivian and Australian concentrates, *i.e.* the bulk of the world's supply, have been treated and refined in England. The price has fluctuated round 11*s.* per lb. since 1914; in 1924 it fell to 8*s.* 6*d.* The metal and its compounds are used chiefly for medicinal, surgical, and toilet purposes, in making fusible alloys and in pigments for painting porcelain, etc. As an impurity in other metals it has remarkable effects on their brittleness and electrical conductivity; thus, one part of bismuth in 8,000 of gold renders the latter unworkable. Antimony is a much more useful metal, especially when alloyed with others, as, for example, in Britannia metal, and in bearing or anti-friction metals. It is of fairly common occurrence, but nearly all the world's consumption is supplied from the province of Hunan, South China, the most important deposit being that at Hsi-K'uang-Shan, which is estimated to contain two million tons of the pure metal. The field is in Chinese ownership. There are also considerable deposits in Algeria and the mines in that district provided most of the metal used by France during the war.

All men of science will much regret to hear of the death of Viscount Leverhulme on Thursday, May 7, after return to England from several months' travels in the tropics. Lord Leverhulme was a generous patron of science. He gave a considerable sum to the Liverpool School of Tropical Medicine many years ago, and has helped other movements. Besides being a consummate man of business, he was also a man of wide intellectual and artistic sympathies.

On January 21 Mr. A. Chaston Chapman, F.R.S., President of the Royal Microscopical Society, delivered his excellent address on "The Yeasts: A Chapter in Microscopical Science." It contains a very interesting quotation from a paper by Martin Folkes in the Philosophical Transactions of the Royal Society of the year 1723, describing the microscopes used by Leeuwenhoek fifty years previously. Some of these, with specimens, had been presented to the Royal Society, but disappeared mysteriously when the Society moved into its present quarters.

Everyone was very glad to learn that the church at Stoke Poges, which was the scene or *locus* of Gray's famous Elegy, has been saved from neighbouring desecration at the hands of builders, by means of public subscriptions amounting to £4,500, which enable the vicar, Canon A. T. Barnett, to purchase the threatened land, and to give it over to the National Trust (*Times*, April 20, and May 6). These subscriptions came from all parts of the world in response to his appeal, and indicate the continued popularity of the great Elegy. What is the reason for this popularity? Because, unlike nearly all other lyrics, ancient or modern, the poem is so carefully clarified in subject, phrase, and music that it is a perfect crystal of beauty. A poet may feel himself inspired to any degree, but without such meticulous filtration as Gray gave to his Elegy the result may be only a poor decoction. We have many modern rhapsodists, but the poet is something much more than that.

The Ross Institute and Hospital for Tropical Diseases, mentioned in previous issues, has now collected within two years half the money originally asked for, which was £50,000; and it has bought a fine house with two acres of ground at Tibbet's Corner, on Putney Heath, and hopes to start work very soon. At the same time we hear from *The Times* (May 2) that the Congregational Forward Movement Fund, which asked for ten times the amount mentioned above, received over £22,000 " in about twenty minutes," thus completing the desired total.

Our new contemporary, *East Africa*, for April contains a very interesting lecture delivered before the Royal Colonial Institute by Mr. C. F. M. Swynnerton, Game Warden of the Tanganyika Territory, on " The Problem of the Tsetse Fly." " Were it a human enemy that was occupying our territory and oppressing us," said the lecturer very appositely, " no effort and no expenditure would be too great for its dispossession. Why, because it is an insect, should we suffer it more patiently ? " Because, we reply, the human race in the mass, including the politicians, has not yet evolved sufficient brain-power to understand that it is worth while spending money and labour against diseases which kill or maim millions of men or cattle or crops, just as it is worth while spending money against human invaders.

The same excellent publication for April 16, p. 646, contains an erroneous quotation from another lecture, implying that the pathogenic rôle of the tsetse fly was discovered by Sir Ronald Ross. The lecturer meant Sir David Bruce, K.C.B., F.R.S.

Major J. B. Paget, in *The Times* of April 23, discussing the humane slaughter of animals, tells us that in Australia public abattoirs are in use (after much original opposition), the cattle being killed by " humane-killers " instead of pole-axe or hammer. In England we have 20,000 private slaughter-houses where, apparently, the old methods of slaughter are still in use.

Prof. H. B. Fantham, Witwatersrand University, gave one of the most lucid accounts of Mendelism which we have read in a paper on Heredity in Man, published in the *South African Journal of Science*, November 1924, Johannesburg.

Messrs. G. Bell & Sons have produced the third of their useful little *Classics of Scientific Method*, entitled *Joule and the Study of Energy*, by Dr. Alex. Wood, of Emmanuel College, Cambridge. It contains 84 pages and 8 plates ; and deals with Joule's work after a very clear exposition of the previous ideas on energy, motion, and heat which led up to his classical experiments. The last chapters deal with subsequent developments.

We have received an advertisement of the new proposed " British Institute of Philosophical Studies." Its temporary office is 88, Kingsway, London, W.C.2, and the Director of Studies and Secretary to the Council is Sydney E. Hooper.

On May 21 Dr. N. V. C. Lothian, Dr. Samuel Darling, and Mlle Besson, members of the League of Nations Malaria Committee, were killed in a motor-car accident near Beiruth, and Dr. Schwellengrebel and Mme Delmas were injured. Dr. Darling was Pathologist for some time during the antimalaria work at Panama, and Dr. Schwellengrebel is a well-known worker on tropical diseases.

The lamented death of Sir Rider Haggard, on May 14, after a painful illness, removes one of the greatest masters of romance, who did for South Africa what Scott, Hugo, Dumas, and Cooper achieved for other parts of the world. He wrote also a masterly work on Agriculture, and contributed to social improvements and to the defence of science against those who attacked it.

The *Indian Medical Gazette*, Calcutta, is to be congratulated upon its constant advance in size and merit. The February number contains an admirable supplement by Major R. Knowles, I.M.S., on the year's medical work in India, and an equally good leading article on the same by Colonel J. W. D. Megaw. The enthusiasm and capacity of Indian medical research workers is now placing them in front of nearly all investigators of tropical medicine. They are original, assiduous, and not so much given to rushing into wild hypotheses as the investigators of certain countries which we need not specify. One is only amazed that the Government of India does not seem to recognise their extraordinary merit.

We have received a draft of the Memorandum of Evidence Presented by the Medical Practitioners' Union of the Royal Commission of National Health Insurance, 1925 (56 Russell Square, W.C.1.). The paper contains detailed studies on the future of National Health Insurance and remuneration.

An amusing scientific work (if such a thing can exist) is a small pamphlet called "Arresting Disclosures: A Report of the Strange Findings in Undergarments Washed with Soap and Water, and Popularly Supposed to be Clean and Wholesome" (J. & J. H. Vice, Leicester), by John A. Bolton, M.I.H. The little book is profusely illustrated with 130 photographs of the extraordinary findings in the said underclothing after it has been purified by our great laundries. Fortunately most of the vermin appear to have died during the process, though their corpses still seem to litter the field.

ESSAYS

ONE HUNDRED YEARS OF AGRICULTURAL SCIENCE

(G. E. Fussell).

THE earliest of our national writers on agriculture, Fitzherbert, acknowledged the relation of science to practical work. Throughout the succeeding four centuries, English writers have laid increasing emphasis upon the necessity for the farmer to adopt the scientific methods which the growth of knowledge has placed at his disposal. If he would only do this, he would not only increase the national output of foodstuffs, but he would also largely increase the profits of his farm.

The benefits scientific knowledge has conferred upon agriculture are not to be depreciated, but for the last two centuries they have been so enthusiastically stated that there is now little doubt of the exaggerations of the protagonists. Possibly that is because the practical farmer has failed to appreciate the consistent advice given him by writers of agricultural books, and by scientific investigators. He has not, in fact, made the most complete use of the knowledge and learning they have placed at his disposal.

Lately a tendency to depreciate the results of scientific agriculture has appeared. One or two investigators have examined the estimates of crop production, made from time to time by contemporary writers, and have come to the conclusion that the late nineteenth century has not seen so consistent an increase in output, particularly of grain crops, as took place in the five hundred years preceding that century. Mr. F. L. Engledow, of the School of Agriculture, Cambridge, writing in the *Journal of Agricultural Science*, made this point, and to some extent elaborated it in a paper he read before the Royal Botanical Society. Other recent papers dealing with the subject have been published by Harriet Bradley, Reginald Leonard, Simkhovitch, and Lord Ernle.

The tendency is always to swing from one pole to the other, and the outlook of all these later writers is decidedly pessimistic. They, in opposition to their earlier colleagues, do not think that the amount of scientific investigation already carried out has yielded results compatible with the effort made. This pessimism has found expression in an emphasis of the law of diminishing returns, and to some extent in the belief that the limit of output of foodstuffs, meat and grain, has, for practical purposes, been reached in this country.

The law of diminishing returns, of course, connotes that the increasing application of capital and labour to a given area of land does not afford a proportionate increase in output, and that, at a certain point, not necessarily determined, the additional expenditure of capital and the additional application of labour does not, in fact, produce any additional output at all. This is no doubt true so long as the methods employed do not become more efficient, but it is the mission of science to provide new methods, and to indicate new systems, both in the mechanical and physical realms, to enable the farmers to apply further effort and further capital to the land, in such a way that the law of diminishing returns is rendered ineffective. The application of improved scientific methods should enable the same area of land to produce an additional output, at least proportionate to the extra effort involved, and should possibly obtain an extra output more than proportionate to the extra work and capital invested. It is possible that this ideal has not yet been reached, but it must be recalled that the real measure of scientific knowledge acquired in the past hundred years is so far comparatively slight compared with the fields that are indicated as necessary to be explored.

To obtain the best results of the most complete application of science to a national industry, it is necessary for the State to take a large part in the subsidisation of research, and in the promulgation of the knowledge acquired. In England, the State, as such, has only very recently accepted its responsibilities in this direction. An excellent synopsis of the development of agricultural science during the past hundred years was given by Sir Robert Robertson in his Presidential Address to Section B of the British Association at Toronto this year, and I shall take the liberty of quoting from this address :

" The connection of the State with scientific agriculture goes back to the beginning of the nineteenth century. The period from 1770 to 1820 was one of great activity in agricultural development. It was then that several of the oldest agricultural societies were formed, and the Chair of Agriculture and Rural Economy founded in Edinburgh University.

" The first Board of Agriculture was formed in 1793, and it was to this Board that Humphry Davy, himself one of its members, delivered during the years 1802–12 the courses of lectures which were afterwards published under the title of *The Elements of Agricultural Chemistry* . . .

" No great advance was made for many years, and when it did come it was at the instance of private enterprise. To John Bennet Lawes, the founder of Rothamsted, is due the initiation of experiments which began in 1834 and have continued uninterruptedly until to-day. Joseph Henry Gilbert joined Lawes in 1843, and the association of the two was not broken until Lawes's death in 1900. When Gilbert died, in 1901, Sir A. D. Hall became director, and he was succeeded in 1912 by the present director, Sir John Russell.

" The next experimental station in England was that founded by the Royal Agricultural Society, on the Duke of Bedford's estate at Woburn under the direction of Dr. A. Voelcker, and now carried on by his son, Dr. J. A. Voelcker. The Royal Agricultural College at Cirencester was founded in 1845.

" The development of the scientific study of agriculture was thus left largely to such institutions as that of Rothamsted, and to certain agricultural colleges which did not receive State aid.

" The first legislative action on behalf of agriculture with which the chemist was concerned was an Act for the protection of the agriculturist against fraud from the purchase of inferior or worthless manures and feeding stuffs. By the Fertilisers and Feeding Stuffs Act of 1893, superseded by the Act of 1906, the seller of artificial fertilisers and certain classes of artificially prepared feeding stuffs was compelled to give, with the goods, an invoice guaranteeing the percentages of specified constituents on which the value of the article depended, and county authorities were required to appoint agricultural analysts for the purpose of checking the statements on the invoice by analysis of samples. The Board of Agriculture also appointed a chief analyst who was required to analyse the reserved samples in cases where discrepancies were of such a nature as to lead to the possibility of proceedings in Court.

" It will thus be seen that, with the exception of the encouragement given to the work of Davy, the first State action was not towards the development of agriculture, but for the repression of fraud. There were, however, movements from time to time in the direction of scientific inquiry into problems connected with agriculture, such as investigations into the effect of food and breed on milk, and into the efficiency of sheep-dips, with both of which the Government Laboratory was closely associated.

"No systematic educational work in scientific agriculture was attempted in Great Britain before 1909, when an Act was passed allocating annually the sum of £500,000 for "aiding and developing agriculture and rural industries by promoting scientific research, instruction, and experiments in the science, methods, and practice of agriculture (including the provision of farm institutes)." Under this Act, a system of agricultural research was framed, based on university and on research institutions like Rothamsted, and linked up with the agricultural colleges. The scheme formulated enabled the Development Commissioners appointed under the Act to form new institutes as well as to extend the existing ones. Rothamsted was largely extended, and increased facilities afforded for work on Plant Physiology (Imperial College), Plant Breeding (Cambridge University), Animal Nutrition (Cambridge), Dairying (Reading), Animal Pathology (Royal Veterinary College), and on similar subjects. In many of these the chemist was essential. Another part of the scheme was the foundation of scholarships awarded to selected graduates of universities tenable for a three-year course of research. In certain selected teaching institutions technical advisers for farmers were appointed, and researches not capable of being pursued at an institute were maintained elsewhere."

The results of these efforts has not been altogether negligible, although by no means remarkable. The work was not really organised before 1909, and it has not yet attained the development which may be expected in the near future. At the same time, there seems to have been an increase in the yield per acre of main foodstuffs during the period under review. A complete description of the position could only be offered by means of a large number of tables of statistics which does not seem desirable here, particularly as it is hoped to publish them in a more appropriate place; but some figures must be quoted. The estimates of the early years of the century are not altogether reliable, although they show a certain uniformity which renders them to some extent probable. It will, therefore, perhaps, suffice to say that the number of cattle in the country in all probability increased during the nineteenth century from about five million in 1800 to nearly six million in 1911. The number of sheep probably decreased from about twenty-five million at the same time to about eighteen and a half million in 1911, as indeed, it has during the period when more or less accurate agricultural statistics have been officially collected. The average number kept during the ten years 1867–76 was about twenty-two million, while the average during 1907–16 was eighteen and a half, as stated above. In both cases the increase in the average carcase weight of animals slaughtered seems to have been considerable, and any decrease in the number of sheep is undoubtedly more than compensated for by the increased average weight of each animal, while the increased number of cattle, combined with their earlier maturity, does not need any comment. Something approximately similar can be said with regard to pigs. So far as the grain crops are concerned, there is no doubt that the average output per acre of wheat has increased in the last 150 years from about twenty-three bushels to about thirty-one. Oats is about the same as it was at the beginning of last century, thirty-nine or forty bushels per acre, whereas barley seems to have decreased by about eighteen per cent., *i.e.* from 39·4 to 32·5 bushels per acre, and in 1878 is estimated to have reached an output of nearly forty-five bushels an acre.

When the figures of grain output were first compiled an arithmetic comparison of the results seemed to provide conflicting evidence with regard to the effect of the application, so far as it has taken place, of improved scientific methods to our national agriculture. It seemed surprising to find that wheat had so much increased in average yield, while oats had risen and then fallen to its original yield, and barley had done the same, the decrease in the last carrying it so much lower than its earlier level.

Various suggestions have been made to account for the peculiarities of the figures. For instance, it has been suggested that, during the period of the Napoleonic Wars, wheat was being grown on a colossal scale and in thoroughly bad conditions, lack of machinery, shortness of labour, and freshly broken land, in addition to which the period was marked by the presence of a bad epidemic of rust and bunt. Barley was only grown where the conditions were favourable, with the result that the yields, compared with wheat, were fairly high. Up to 1870 wheat was our national crop, and the big area under it was well farmed because prices were, on the whole, very satisfactory. Barley was still relatively a small crop, even in the recognised barley areas, such as Norfolk, and was mainly grown where crops were high. When, in the eighties, wheat began to diminish in area, barley and oats took its place, and the high wheat yields may be a reflection of the crop survival on the better soils, while the lower barley yields may similarly reflect a widening of the area on which it was grown, and its consequent cultivation on soils not so well fitted for it. This explanation appears reasonable, but an examination of the estimates of area involved does not support it. There does not seem to have been any considerable extension of the area upon which barley was grown, the available estimates indicating that the crop had covered about 2,000,000 acres round about 1850, from which it began to decline, and came down to about 1,500,000 acres, which was probably the area it covered towards the close of the Napoleonic Wars. The decrease in the area of wheat is a commonplace of agricultural pessimism in this time. With regard to oats, the area has been slowly increasing from the '70s of last century, but not in any such marked degree as would give real credibility to this theory.

It has also been suggested that some explanation of the discrepancy between the increase in average wheat output per acre and the decrease in the other two main crops grown will be found in the fact that agricultural science has concerned itself more particularly with the development of good strains of wheat at the expense of the other two crops. A very large amount of work has been done on all three of these grains, and I do not think that this theory is any more tenable than the other.

The exceptionally high yields of barley and oats said to have been obtained in the middle of the nineteenth century may perhaps be explained in another way, although the explanation now offered is only a surmise. The collectors of the material, which forms the basis of these estimates, did not obtain universal returns from all farmers. Even the official collectors of statistics failed to do this, although the returns they compiled are undoubtedly practically complete ; but the amateurs, such as the farming newspapers and the Chambers of Commerce, did not attempt to do so. They contented themselves with the collection of a few hundred returns, probably obtained from prominent farmers, whose average output was naturally on the high side. The mid-century figures may, therefore, require to be reduced, if a true view of the development of the art of agriculture is to be obtained. These figures are, however, consistent, but that may be because they were obtained from a limited number of good farmers, and may not be a proof of their validity.

It would be better, for purposes of comparison, to ignore the mid-century figures because they may be fallacious, and to base any conclusions upon a comparison of the early part of the nineteenth century with the early part of the twentieth; but, although that may be the safer course, it is necessary to regard the present conclusions as tentative only.

Finally, it may be well to recapitulate the results achieved. There can be little or no doubt that the output of meat has largely increased during the hundred years in spite of any apparent diminution in the number of animals kept, although there has been no such diminution in the number of cattle. The average output per acre of wheat has decidedly increased. The only grain which has really decreased in produce per acre is barley, although oats at one time during the century seems to have been at a very much higher average level than it was immediately before the war. The very large importation of foodstuffs, which is a commonplace of our social organisation, makes it perfectly clear that we are not keeping pace in the national output of foodstuffs with the increase of our population; but that again is a question which cannot be dismissed in a sentence; it must be very carefully examined before any definite pronouncement can be made. It is just as true that we were not producing the whole of our foodstuffs from national sources one hundred years ago, when our population was only a quarter of what it is to-day. What is clear is that agricultural science has, at least in some measure, already abrogated the law of diminishing returns, its peculiar function in connection with agriculture. It is not unduly optimistic to think that the progress of the acquisition of knowledge will continue at a much more rapid rate in the immediate future than in the immediate past, because the whole range of scientific knowledge is developing much more rapidly to-day than it has ever done. Consequently the output of our agriculture will be proportionately much more rapidly increased in the future than it has been during the past century.

But, to ensure that this result is obtained, it will be necessary for those who acquire scientific knowledge to see that it is applied to the industry; or, rather, for it is hardly their business, it will be necessary to make increasing provision for the education of the farming community, and for some measures to be adopted to ensure that the competence of the land workers of all grades is adequate to their functions.

I cannot do better than quote Dr. Crowther's words on this subject. In concluding his paper on "Science and the Agricultural Crisis" read before the British Association in 1923, he said:

"Whatever the character of our land-tenure system of the future, it is certain that sooner or later some guarantee of efficiency for the productive occupation of land will be demaded from the would-be farmer. We cannot continue indefinitely, on one hand, to proclaim that the land is our greatest national asset, to be maintained with the help of, and in the interests of, the State in a highly efficient state of productivity, while, on the other hand, the use of the land is left open to all, regardless of fitness for its effective use. This vision of farming reduced to the status of medicine and law as a close profession regulated by an entrance examination, may perhaps be stigmatised as a horrible nightmare; but some movement in that direction I believe to be inevitable, and, with nationalisation of the land, it might well come more speedily than one would venture to contemplate. None will question, at any rate, that, should such a day arrive, education in the principles underlying the calling will loom as largely as practical training in determining the standards of admission to the use of the land."

SANDERSON OF OUNDLE AND PREPARATORY EDUCATION

(V. Seymour Bryant).

In the Preparatory Public School system of this country two methods are adopted. One group of schools recruits its boys mainly, though not solely, from Preparatory Schools which are private enterprises, entirely independent of the Public Schools to which their boys will eventually proceed.

A smaller group of Public Schools, however, *e.g.* Cheltenham, Oundle, Cranleigh, etc., have preparatory departments of their own, and, although these are not sufficiently large to fill all the vacancies in their respective senior schools, still a proportion of the boys pass through the schools in this way.

This system has the great merit that it obviates one of the very marked flaws in the Public School system: the lack of liaison between the two stages of a boy's career. The relative standards of work in different subjects in the lower forms of Public Schools differ necessarily from the relative standards in the higher forms of Preparatory Schools, and the natural tendency is to place a new boy at a Public School according to the standard he has reached in his weakest principal subject. The result of this is that in all his other subjects a boy is marking time for, it may be, several terms. During his first year there is, therefore, every encouragement for a boy to take his school work very casually indeed, and the habit, once engendered, is difficult to eradicate. During the last decade this difficulty has become intensified owing to the development of science teaching at the Public Schools. Science, which in many cases was previously only begun in the middle forms of Public Schools, is now pretty generally taught in the lower forms as well, whereas, in spite of the recommendations of the Prime Minister's Committee in 1918, Science is not taught in Preparatory Schools except in very rare cases. The result of this is frequently that an able boy who would, in the normal course of events, take quite a good place at his Public School, has to take a considerably lower form in order to receive the necessary elementary instruction in Science to prepare himself for the school course in that subject.

The great advantage, then, of preparatory and public school education under the same authority is that of continuity; but there are several disadvantages. Not the least of these is that, under such a system, a boy, for the nine or ten years of his school life, lives in the same atmosphere, climatic, social, and educational. A new outlook, with its freshening influence in every way at the mid-point of a school career, is of great value.

During the last few years of Sanderson's life the problem of preparatory education was constantly before him. He had a small junior house at Oundle, the Berrystead, but the great majority of the boys were entering Oundle from other Preparatory Schools. The pressure of application for entry was very great, the waiting list of boys already entered, passed, and accepted was a lengthy one, and yet acceptance of such boys at the age of fourteen was a block in the way of his own boys passing on to the senior school when they had reached the required standard of knowledge and age. He therefore decided gradually to abolish his own preparatory department, and so to secure additional accommodation for the senior school which was so sorely needed. Such a course would have the advantage of removing the difficulty of the wedge at the age of fourteen, but would destroy the only liaison which existed between the two stages of a boy's educational career. He did not live to carry out his intentions in this matter, but during the years 1917 to 1919 he was continually on the search for a Preparatory School to which he might divert the boys entered for his own preparatory department which he could not accept owing to lack of room.

As can be imagined, such a school was not easy to find, as his requirements were many. In the first place, he was strongly opposed to the system of selection for entry to Public Schools by means of the Common Entrance Examination. His first necessity was to find a school with whose head master he could work in close co-operation and upon whose judgment he could rely in the direction of advising him as to what boys to accept for entry to Oundle quite independently of the examination results themselves, which he knew were most misleading.

Not less important was the question of as complete a liaison as possible between the work of the higher forms at the Preparatory School and the lower forms at Oundle, so that a boy might pass quite smoothly from form to form without that educational break to which reference has already been made. He ever realised that his was the voice of one crying in the wilderness, and few head masters of his day either realised his aims or sympathised with his ideals.

He further recognised that the Oundle system, in its details, would need considerable adjustment to meet the needs of younger boys, and, whilst maintaining his general principles, he sought for an established Preparatory School which would be prepared to carry out educational experiment and research in that direction.

He failed to discover the school he wanted, and discussed with me the possibility of my starting a school which should embody his general principles. After much hesitancy I agreed to attack the problem, and St. Piran's, Maidenhead, was launched in September 1919, with twenty-three boys deflected from the Berrystead. In a very short time the school was full, and tentative schemes began to crystallise.

Sanderson's views at this time may be worthy of record, and in a Foreword which he wrote for me in 1919 he said:

"In these days there is a wide field to explore and much work to be done—all of which will engage the talents and excite the imagination of young boys. In the first place, boys will have the opportunity of becoming good craftsmen, in workshop, in library, and in field. Quite young boys can do useful work in shops, learning the craftsman's art and lore, and they can do similar work in a well-equipped library, and in outdoor life. This creative work is natural to boys, and leads to co-operative methods. Instead of much of the traditional class-work, boys may be set free to research, draw, make maps, charts, or merely read in library and art-room. Even the youngest boys can be put to useful work in a co-operative scheme. The master will always have some investigation in which he will be glad of the help of his boys, and it is astonishing how much can be learnt in this way. It will also lead to a new attitude of mind and outlook.

"Again, young boys can be set to work with machinery—heavy machinery, such as will excite the imagination, create the scientific sense, and incidentally give exercise for mathematical talents. Engines, motors, dynamos, testing machines, and so on, can all be used by young boys.

"The more modern method of acquiring an appreciation of literature by acting is another example of co-operation in schools.

"A prominent place should be found in a Preparatory School for the 'Romance of Science.' It is a good thing to bring young boys within range of the unknown, where research is still going on, to let them see something of adventure in the natural world. There are quite a host of experiments which they can do—and, as it were, play with—experiments which will keep their eyes open and excite wonder and give plentiful inspiration. There are wonderful things in mechanics, electricity, chemistry, biology, and astronomy. Wonderful, too, are the lives of the great men.

"The question may be asked, Where is the time to come from for all these things to be done, and done properly? The answer is that abundance of time may be taken from all the ordinary class-room teaching, and especially from the time spent over Latin. Latin need not be started so early, and the time given to it may be considerably reduced, and all to the advantage of the Latin itself. We believe that this larger field of work and the new outlook which it gives, will be all for the benefit, not only of Latin, but other school studies.

"The wider curriculum sets free many and diverse talents. Boys will be judged by what they can do, and not by what they cannot do. It is disastrous, we think, for boys to be judged and classified by their attainments in one conventional subject. Each boy should be given the chance of developing his special faculty, and to give this chance is the paramount duty of a school.

"The study of Languages, of Mathematics, of English, will benefit by this outlook in school life.

"It is because I believe Major Bryant is all in sympathy with these views that I am deeply interested in his new work—work which I think is urgently needed to be done."

The original conception was Sanderson's, the initial schemes of work were his, and his influence and advice determined to a considerable extent the development of the school during its first three years. Whatever success has attended the efforts made must therefore be looked upon as a tribute to the memory of one who, in addition to being the greatest head master of his age, was the keenest of critics and the kindliest of friends.

It is only possible to indicate in a very cursory manner the general principles upon which the school was built up and the methods employed to achieve those ends. In attacking the problem of preparatory education, the necessity for an entirely new basis seemed urgent. The centre of gravity of English life, wealth, and thought had shifted during the war period to an extent not fully appreciated even to-day; power had to a very great extent passed from the old governing and aristocratic class to the producing class, from the authoritative section of the community to the creative. It appeared evident that education itself should become creative, that the mere absorption of knowledge should give place to the development of latent faculties, so that evolution might proceed along the lines of the literal interpretation of the word "education"—a "leading out," rather than a "driving in." The revision of old methods or the substitution of new ones, so that knowledge might be acquired and not instilled, might become, so to speak, a by-product, obtained, when possible, indirectly through action and co-operation: this was the bed-rock of the educational experiment which has been proceeding here for the past six years.

On this foundation an attempt has been made to erect a superstructure embodying as far as possible the principles suggested in the report of the Prime Minister's Committee under the chairmanship of Sir J. J. Thomson, which was published in 1918.

> "In the examination for entrance scholarships at most of the Public Schools, the papers set in Classics are of such a character that to do well in them a boy must have devoted much more time to this subject than to any other. . . . As great weight is assigned to these papers . . . it results that (i) some boys whose abilities lie in other directions than Classics miss the encouragement which is legitimately attached to the winning of a scholarship, (ii) others are enticed along a path which does not lead them to their true destination, (iii) the curricula of many preparatory schools are naturally distorted.
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> . . . . . .
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> "We cannot think that there is any natural distribution of ability in relation to literary and scientific studies which corresponds in any way to the actual distribution of scholarship awards for these two kinds of study; and it is impossible to avoid the conclusion that the effect of existing entrance scholarship examinations at the Public Schools is to divert to specialised literary and linguistic studies of a particular kind boys who might have been successful in other fields." (Section 18.)

One of the first things to do, therefore, was to smooth out this unnatural distortion and to diminish the usual number of hours devoted to Latin in the average Preparatory School. Latin now is on the same footing as English, French, and Mathematics as far as hours in the curriculum are concerned.

From the point of view of scholarship winning, this was of course a serious change; but, by abolishing the "hot-housing" of the few, the welfare of the many was enhanced.

The position of Science in Preparatory Schools remains where it was in

1918. The report referring to replies to a questionnaire circulated to Preparatory Schools, and to the answers of witnesses, states:

> "From these answers it appears that, in the majority of the 307 Preparatory Schools replying, no provision is made for the teaching of Science (including under this head Nature Study and Practical Measurements) as part of the regular curriculum. It is even more significant that, while the Report drawn up by the Joint Committee of the Head Masters' Conference and the Association of Preparatory Schoolmasters, and adopted in 1916, includes an appendix on Elementary Science Training, no time is allotted for science teaching in the time-table suggested for Preparatory Schools.
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> "There are, in our opinion, sound educational reasons for postponing the beginning of the systematic study of Chemistry and Physics till the age of 12½ or 13, apart from the fact that the schools in question have not the necessary staff or equipment to undertake work of this kind. But it is much to be regretted that, as an introduction to more formal work in Science, there should be no preliminary instruction in Nature Study, broadly interpreted, or in Practical Measurements. Further, it does not appear that the omission of such teaching is compensated for by increased attention to Handwork or Drawing.
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> "There is no doubt that, in framing their curricula, the preparatory schoolmasters have been largely influenced by the requirements of the entrance examinations and entrance scholarship examinations at the Public Schools. It is also clear that, while these examinations are designed to test the knowledge and ability of boys in English subjects, French, Latin, Mathematics, and sometimes Greek, knowledge of such Science as might properly be taught to boys of preparatory school age is either not tested at all or tested only in an incidental manner. Again, until three years ago, Nature Study was included as an optional subject in the Common Entrance Examination for Public Schools; but we were informed by one of the representatives of the Preparatory Schools Association that 'few candidates took it, the reason being that the subject was not required as a condition for entrance to Public Schools.'
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> "It is most unfortunate that the curricula of many Preparatory Schools should be so far determined by the examination requirements of the Public Schools as to lead to the omission or comparative neglect of subjects which are appropriate elements in the education of boys of preparatory school age. Quite apart from the question of examinations, we are of opinion that all Preparatory Schools should make regular provision for the teaching of the elements of Natural Science with Handicraft and Drawing. By the elements of Natural Science we here understand what is known as Nature Study, *i.e.* physiography and an elementary study of animal and plant life, together with practical exercises of the kind referred to in para. 48.
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> "The elements of Natural Science thus defined should, in our opinion, be a necessary subject in the entrance examination of Public Schools."

Section 48 reads as follows:

> "This course should be of as practical a character as possible, and should aim at arousing an interest in natural phenomena and developing the powers of observation. Full use should be made of the opportunities afforded by the school garden to make the pupils acquainted with the spirit of scientific investigation. We attach great importance at this stage to manual training, both for the sake of the discipline it supplies for hand and eye, as making an excellent introduction for laboratory work. We think that advantage should be taken of the opportunities which nature study and manual training afford for practice in freehand

> drawing and drawing to scale. . . . The right remedy lies in a more intelligent treatment of Arithmetic and Handwork in the Preparatory Schools. Advantage should be taken of the opportunities afforded by lessons on Arithmetic, Geometry, Geography, and Handwork to introduce the idea of measurement, to give practice in the use of simple measuring instruments—a valuable exercise in manipulation—and, lastly, to develop both readiness in the making of calculations and an appreciation of the degree of accuracy to which results may be stated."

A serious attempt has been made at St. Piran's to carry out all the above recommendations in the spirit as well as in the letter. The neglect of science teaching in practically all Preparatory Schools has serious effects upon a boy's public school career, quite apart from his ignorance of the elements of a subject which he should know.

The report, after pleading for increased attention to practical work, continues:

> " The introduction of practical work into the curriculum widens the opportunities of discovering ability which might otherwise be overlooked. One witness writes: ' Often, very often, the dunce of the form, when put on to practical work, becomes brilliant.' It is the function of any system of education to discover ability as well as to develop it, and under a system in which the curriculum is entirely bookish many able boys may be depressed, and lose all interest in their work from want of success and of opportunity to reveal their ability."

The above paragraph is perhaps one of the most pregnant of the comprehensive report. This point of view is rarely recognised or pointed out, and it is worthy of the closest consideration by all who are interested in the education of boys of preparatory school age particularly.

> " Too few parents of this generation can satisfy their children's curiosity about the wonders of the heavens, the movements of the planets, the growth of plants, the history of the rocks, the dawn of animal life, the causes of tide and tempest.
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> " How necessary Science is in war, in defence and offence, we have learnt at a great price. How it contributes to the prosperity of industries and trade all are ready to admit. How valuable it may be in opening the mind, in training the judgment, in stirring the imagination, and in cultivating a spirit of reverence, few have yet accepted in full faith.
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> " A nation thoroughly trained in scientific method, and stirred with an enthusiasm for penetrating and understanding the secrets of nature, would no doubt reap a rich material harvest of comfort and prosperity; but its truest reward would be that it would be fitted by an ample and generous education to perform justly, skilfully, and magnanimously the offices both private and public of peace and war." (Introduction.)

In addition to providing facilities for the study of Elementary Science and for Wood-work and Metal-work, schemes for the practical treatment of Mathematics and Geography had to be devised. Drawing and Class-singing also claimed attention.

Quite apart from curriculum changes, two guiding principles had to be kept in view: the utilisation of co-operative methods as far as possible and the stimulation of a spirit of discovery and research.

The scheme was an ambitious one: no previous data were available for guidance, but, on the other hand, no fetters could be imposed from without. The difficulties in the way of the realisation of these aims have been many, but most of them have been overcome. Of finance it is hardly necessary to refer except to say that, apart from many generous gifts from enthusiastic parents, no grants or external aid of any kind have been employed. Two other difficulties, however, need mentioning.

In the first place, one was confronted with the problem of time, and this has been overcome to a great extent by three devices. At the very outset attempts were made to correlate as far as possible the teaching of the various subjects and to "dovetail" in various directions. Mathematics, Handicraft, Science, and Drawing, for example, were admirably adapted to such blending. The teaching of English, again, was readily interwoven with instruction in other subjects: team-work amongst the staff is, of course, vital to success in this matter.

A reduction in the number of hours usually devoted to Latin has also helped to provide additional time, although this economy is partly offset by some of the periods so saved being ear-marked for what is somewhat grandiloquently called "Classics." This consists, in the case of the youngest boys, of myths and legends of ancient Greece and Rome. The middle sets get some conception of the value of the legacy we have received from the Far and Near East of ancient times, whilst the top form in the school makes some sort of a connected study of Ancient History. Possibly by such methods a greater interest has been aroused in the literature and philosophy of Greece and Rome than by spending the time upon attempting to obtain meticulous precision in the grammar of the languages themselves.

These two avenues were fully explored, but far more time was yet needed. No mere actual in-school hours were available; out-of-school hours obviously had to be employed. As a consequence, much of the work had to be put upon a voluntary basis, and societies were formed. The enthusiasm for these societies at the very outset was remarkable, and, as new societies have been added from time to time, the keenness seems to increase rather than to diminish. Although the school only accommodates some 60 boys, the average membership for each society is somewhere about 25 or 30. They have become a fundamental and vital part of the whole educational scheme, probably even more fruitful in their results than the in-school work hours themselves. It has, at any rate, been fairly conclusively proved that boys will learn readily enough if schoolmasters will only let them! The societies at present in active existence are:

(i) The Natural History Society, with three sections.
(ii) The Engineering Society.
(iii) The Wireless Society.
(iv) The Photographic Society.
(v) The Literary Society.
(vi) The Gardening Society.

In the Christmas Term there is also a Choral and Dramatic Society, and the members of the Engineering Society are at present engaged on making rain-gauges, an anemometer, a thermometer screen, etc., for a meteorological society to be started shortly. The work of these societies is of the most interesting nature, but cannot be referred to in greater detail.

The second difficulty was that of accommodation and equipment. The premises, when taken over in 1919, were admirably adapted for the normal school work, and in fact were built especially for that purpose. For the broader treatment already outlined they were naturally deficient. It is true that an excellent carpenter's shop was already in existence, but a science laboratory had to be provided, and also an adequate boys' library. Music-practice rooms were built, a cinematograph installed, and the members of the Natural History Society erected their own little building in which their aquaria and breeding cages, etc., are housed.

Further accommodation, however, was needed, and during the early part of last year a new science block was built. This includes an engineering shop, the equipment of which meets all our needs, and which was presented to the school by various parents, a drawing office, technical library, and a photographic section. The latter consists of a safe-light corridor leading to two dark rooms, one for developing and the other for printing and enlarging. The accommodation is therefore now both ample and complete.

It is held in some quarters to-day that the field covered by schools educationally is far too wide, and the opinion is frequently expressed that the subjects of the school curriculum are already too numerous. What justification exists for providing facilities for the development of interests such as woodwork, engineering, photography, wireless, natural history, gardening, and so on ?

The answer may be summed up in the single word " stimulus." But the psychological effect of stimulus may often be more harmful than beneficial. Every school works upon the basis that some stimulus is necessary in order that the results aimed at shall be attained as far as possible. A school affording no stimulus at all is unthinkable. In order to judge of the suitability of such what criterion shall we apply ?

It is probably admitted that the English Public and Preparatory School system produces a type of character which is altogether admirable, but that the product intellectually is open to severe and well-deserved criticism. Why ? The answer to this—partly, at any rate—lies in the fact that in our best schools the moral stimulus applied is mainly intrinsic, whilst the intellectual stimulus is to a greater extent extrinsic.

The two most valuable stimuli employed in character development are the utilisation of a boy's sense of honour and the appeal of tradition. The value of the former in moral training and in the maintenance of school discipline is widely recognised. The appeal of tradition depends for its success upon the realisation that a boy at school is a member of a social organism, and that every individual action affects the welfare of the society. It is the analogue of the virtues of patriotism and loyalty in the State. Both these incentives are essentially intrinsic: they are inherent, they spring from within, they are dependent entirely on the utilisation of the better qualities of a boy's nature, and are not sanctions imposed from without.

When we come to consider the stimuli employed in intellectual development, however, we find that they are almost exclusively extrinsic, and mainly individual and arbitrary ; at the best they are of little permanent value, at the worst they are even harmful. The struggle for marks, the lure of prizes, the fear of detention, the dread of physical punishment, the anxiety to secure personal superiority over one's fellows—all these are examples of external stimuli in common use. The effect on the stronger boy is individual glorification at the expense of the social community ; the effect on the weaker is the acceptance of a sense of inferiority, lack of self-confidence, and loss of initiative, which, if they persist through life, will have results which are obvious. External stimuli, however, cannot be entirely eliminated in practice, either in moral or in intellectual development. The wise schoolmaster has already reduced them to a minimum, so far as character training is concerned ; but, from the intellectual point of view, much yet remains to be done. Once realised, this is a matter for experiment and research. The discovery of each boy's instincts and impulses is far from easy, but these, after all, are the main determining factors in his future conduct. The success or failure of a school, from an intellectual point of view, cannot be judged accurately from examination results. It is, however, dependent upon the ability of those in authority to discover these inborn instincts and impulses, and to afford sufficient opportunity for them to develop. If these are repressed, or not given full freedom for growth, the most valuable stimulus of all is wanting.

One is led to believe that the activities referred to engender a love of work for its own sake which reacts favourably upon the general scheme of work, and further tends to simplify the problem of discipline, which is always with us.

ESSAY-REVIEWS

THE CONTRIBUTION OF AMERICA TO GEOLOGICAL SCIENCE.

By G. W. Tyrrell, A.R.C.Sc., Ph.D. Being a Review of **The First Hundred Years of American Geology.** By G. P. Merrill. Pp. xxi + 773, with 36 plates and 130 figures.] (New Haven: Yale University Press and Oxford University Press, 1925. Price 27*s*. 6*d*. net.)

It is one of the glories of British science that modern views of geology, and especially stratigraphical geology, were first promulgated in these islands, and that our stratigraphical terminology, enshrining many English place-names, has imposed itself practically on the whole world. In igneous geology, too, at the conclusion of the great Neptunist *v.* Plutonist controversy, the victory was gained by the Plutonists, with Hutton the original genius, and Playfair his interpreter, at their head. Nevertheless, in spite of its achievements, British and European earth science was curiously limited and insular for a long period, chiefly because the geology of Western Europe is at once highly complicated, specialised, and in a sense abnormal; and the resulting bias towards certain interpretations based on insufficiently wide observation needed a corrective drawn from the study of the simpler and more uniform geology of the New World. Hence the volume on the history of the first hundred years of American geology, from the pen of Dr. G. P. Merrill, the eminent Head Curator of Geology in the United States National Museum, will prove extraordinarily useful in helping us to assess the contribution of America towards the common stock of geological science, and its influence in introducing a wider horizon and compelling a wider outlook in European geology.

The relative lack of academic training led the earlier American geologists into morasses of crude speculation which were avoided to some extent in Europe. Nevertheless, there was a compensation in their comparative freedom from academic rigidity of mind; and the guesses and intuitions of the more originally minded often sent brilliant shafts of light into the unknown, and led to the rapid advance of the science. One has only to recall in this connection the work of the American school of physical geologists, inspired as they were by the immensity of their field and the broad simplicity of geological structure and process therein. The enormous scale of the phenomena, especially in the West, inspired great ideas which European investigators often could not compass, owing to the spatial limitation of their field, and its division into comparatively small units of unlike characters.

Dr. Merrill's book is essentially an amplification of his *Contributions to a History of American Geology*, published in 1904, and his *History of the State Geological Surveys*, published in 1920. It is a huge royal octavo of 773 pages, in which he has reviewed step by step, and with many personal glimpses, the work of the geological pioneers in America. The progress of geology in Eastern Canada is also treated, especially where the work of Canadian geologists impinged on that of the Americans.

The matter is treated in historical sequence, beginning with the Maclurean Era (1785–1819), of which William Maclure was the central figure. Then comes the Eatonian Era (1820–29), dominated by the work of Samuel Eaton; followed by the Era of State Surveys, the history of which is divided into five decades. The sequence is completed by a chapter dealing with the succeeding Era of National Surveys. The rest of the book is occupied by chapters explaining the development of ideas upon certain leading questions, such as the fossil footprints of the Connecticut Valley, the Eozoon controversy, the Laramie question, the Taconic question, the glacial hypothesis, microscopical petrography, and the age of the earth. There is a long appendix containing letters concerning matters referred to in the text. It may be regretted that it was felt necessary to insert them. They are full of fierce rivalries, peddling jealousies, and squabbles regarding priority; and cause the reader to wonder at the littleness of scientific men in face of the greatness of their work. It is not to be inferred that American geologists, or scientific men in general, are singular in this respect.

The history of American geology opens in the midst of the great Neptunist-Plutonist controversies between the followers of Werner the German and Hutton the Scotsman. Geological science began through the application of the earlier crude ideas by European immigrants to the wider problems presented by the New World. The first systematic work was Schopf's *Beitrage zur Mineralogische Kenntnis der Ostlichen Theils von Nord Amerika und seiner Gebürge*, published in 1787.

The first University chair in chemistry and natural science (including geology) in America was instituted at Yale in 1802, when President Dwight appointed his nominee, Benjamin Silliman. Silliman, who was only twenty-two years of age at his appointment, and had recently been admitted to the Bar, had not even the most rudimentary knowledge of the sciences he was to teach. Yet such was the natural force of the man that, while at first he had to read privately and take lessons from other teachers in his subjects, he ultimately did more than any other man of his day for science, especially geology, through his teaching, public lecturing, and through his foundation of that great periodical, the *American Journal of Science*. Silliman unquestionably foreshadowed the present aqueo-igneous theory of the crystallisation of granite and other igneous rocks, in words that have an essentially modern ring (p. 157). G. W. Featherstonhaugh, too, in 1835, recognised that crystalline limestones and marbles might arise by metamorphism due to contact with *ignigenous* (igneous) rocks.

It is William Maclure, however, who occupies in American geology the same position that William Smith holds in British geology. In 1809 he published *Observations on the Geology of the United States*, with a coloured geological map of the region east of the Mississippi. This was the first real attempt at a geological map of any portion of North America, with perhaps the exception of Guettard's mineralogical map of Louisiana and Canada, which cannot stand in the same category as Maclure's. Maclure was born at Ayr in 1763, visited America at the age of nineteen, but returned to Britain and made a fortune in business before his final settlement in America, where he became naturalised in 1796. His geological map was a labour of love. In the words of his biographer: "He went forth with his hammer in hand and his wallet on his shoulder, pursuing his researches in every direction, often amid pathless tracts and dreary solitudes, until he had crossed and recrossed the Alleghany Mountains no less than fifty times."

The Maclurean Era was one of crude speculation mostly based on the Mosaic cosmogony, yet with occasional clear glimpses of more rational explanations of geological problems. The succeeding Eatonian Era was transitional to the beginning of the modern epoch; the possibilities of State surveys began to be seriously canvassed, and in it the first serious attempts at correlation by means of fossils were made.

After the Eatonian Era come the five decades of State Surveys, and many famous names appear for the first time in the history; as, for example, Edward Hitchcock of Massachusetts; the three brothers Rogers, with H. D. Rogers of Pennsylvania, beyond doubt the foremost structural geologist of his time; James Hall of New York; J. D. Dana of textbook fame; Sir William Logan of Canada; and Sir William Dawson of Nova Scotia. The establishment of a Geological Survey in New York in 1836 was epoch-making in its influence upon American geology. No region could have been more favourable to the establishment of the fundamental principles of stratigraphical geology. The work demonstrated once for all in North America the importance of fossils for correlation purposes, and the occasion produced a man, James Hall, who was destined to become America's greatest palæontologist.

We have already noted one or two instances of acute prevision in American geology; and in the following quotation, summarised by Merrill (p. 225) from W. W. Mather's *Report on the Geology of New York State*, dated 1842, there seems to be a foreshadowing of the present-day doctrine of the westward lag of land masses and their horizontal movement: "The inertia of the solid mass of the interior of the globe would also cause it to press to the westward with a power dependent on the rapidity of rotation. Given then, lines of weakness, where yielding would take place, motion and distortion or elevation might follow. If the interior were fluid and the solid exterior floating upon it, a change in the velocity would produce still stronger effects, and changes of latitude of masses of the earth's surface would result." There is a distinct flavour of Wegener and the hypothesis of continental drift in this.

The close dependence of landscape form on geological structure and process was not at all well understood by the older geologists, and Merrill writes on this topic (p. 146): "One of the points which must impress the reader who is at all conversant with the work of modern physiographers is the inability of Hitchcock, as well as his contemporaries, to understand the relationship existing between a river and the channel in which it flowed." Yet toward the end of the era of State Surveys there arose that brilliant school of physical geologists which was to lead the world in ideas on this and on cognate subjects. The rapid expansion to the west, and the driving of roads and railways through the unexplored country west of the Mississippi, provided the opportunities for the famous reconnaissance geological surveys of the late sixties and the seventies, which represent one of the greatest triumphs of American geology, and produced that galaxy of famous geologists, Hayden, Powell, King, Gilbert, and Dutton.

The plateau country of the Colorado and adjoining States presented unequalled facilities for the study of certain types of geological problems relating to stratigraphical succession, uplift, and erosion. Powell first drew attention to the cutting of gorges by rivers during the uplift of the country, which observation may perhaps be regarded as the starting-point of modern physiographic geology. At this time, too, the ideas of antecedent and consequent valleys, base level of erosion, and other notions which have passed into common geological parlance had their inception. Gilbert also made a cardinal advance in igneous geology by his recognition of laccoliths.

The great national surveys carried out at this time inaugurated a new epoch in American geology. The most important of the expeditions thus begun under the auspices of the central government were F. V. Hayden's Geological Survey of the Fortieth Parallel; Powell's United States Geological and Geographical Survey of the Rocky Mountains Region; and Lieut. Wheeler's Geographical Surveys West of the One Hundredth Meridian. From these beginnings grew in 1879 the United States Geological Survey, which, for breadth of scope, financial resources, and prolific results, is without parallel in the history of the science.

With the establishment of this great national organisation the formal part of Dr. Merrill's history fittingly ends, but the book continues, as noted above, with the history of some special questions. His writing is clear and dignified, as befits its subject; and it is enlivened and diversified by numerous biographical sketches and anecdotes of the men who built up the magnificent edifice of American geology. While it may be too much to say that American geologists lead the world in earth science, they are nevertheless in the very forefront of its advance.

WILLIAM OSLER: SOME PERSONAL NOTES. By SIR RONALD ROSS, being a review of: **The Life of Sir William Osler.** By HARVEY CUSHING. [2 vols. Pp. xvi + 685, and xii + 728.] (Oxford: University Press, 1925. Price 37*s*. 6*d*. net.)

PROF. HARVEY CUSHING (C.B., M.D., Sc.D., LL.D.), of Harvard University, did well not to stint space for the biography of his friend: it is the complete history of a complete man—nothing shorter would have served; for had a shorter one been attempted, Osler's other friends (of whom I hope I was one) would have each lodged a separate protest. This book is what we have been expecting ever since we learnt that Cushing had undertaken the duty; and we are a formidable body: all Osler's acquaintances were his friends. Just the right attitude has been adopted. The book is a temple of entablatures—Osler's letters and portraits; and the author merely leads us from one to another of them. That virile form, not tall, not heavy, instant and various with a spark of vivid energy derived from a real fire of genius in him, appears, stands, or vanishes in every page, as it did in life among us. Most men are terribly the same, and as we grow older we tend to fall together into a few familiar types; but Osler was always different. I figure him to myself standing arm-in-arm with young men on either side of him (all young men gathered round him) to offer us welcome—a grave, keen face suddenly lighting into a jest. His manner and manners were the best American, so unlike ours.

There was no shade of insincerity about his courtesy, nor about his opinions. His conversation flickered from point to point like summer-lightning. He mentioned many persons, but never discussed personalities. There was no censure in him—nor indeed any controversy. He seemed never tired, abstracted, nor lethargic. Though medicine was his first preoccupation, yet in a moment he would turn off into some garden of philosophy and gather one a flower or two there ; and he remembered everything, including his listeners.

I think I met him first at Liverpool in 1901, just before I started for Sierra Leone in order to give a practical demonstration of my method of " mosquito-reduction " against malaria ; but I was too full of the scheme to remember details. After several subsequent meetings at various congresses, we were together, or at least in proximity, at Guernsey in the summer holiday of 1903, where we swam and fished. In 1904 I returned with him from the World's Fair at St. Louis to his house in Baltimore, where I revenged myself for a joke he played upon me in the train by finding mosquito-larvæ in his back yard, as mentioned by Dr. Cushing—Osler, who had failed to find the larvæ, having declared that the adults had been blown into the town by the wind. Next year he was appointed Regius Professor of Medicine at Oxford. In 1911 he received a baronetcy, and he, Lady Osler, and their son Revere spent the summer holiday at Llanddulas on the north coast of Wales, at my suggestion, Sir David and Lady Bruce and ourselves being also there—we had received the K.C.B. at the same time. During the war I had often to inspect a malaria-hospital at Oxford, and visited the Oslers several times. Then came the loss of his son at the front in 1917—I had lost my elder son at the beginning of the struggle. Osler died at the end of 1919, at the age of seventy, in consequence of a " cold " caught while he was motoring back from Edinburgh during the railway strike.

What was his exact place in the medical hierarchy ? Medical work is of three classes—practice, teaching, and investigation. In this country—which is now, let us hope, approaching the promised land of civilisation—the practitioners still constitute the most important branch of the profession ; they obtain (if successful) the principal honours and titles ; they manage the profession through learned or academic bodies ; and it is they alone who can ever collect any wealth from their work. A few centuries ago they constituted the whole profession in England, just as they now do in most eastern countries, and the prescriptions of our most learned physicians were precisely similar to those of any *hakim* to-day. Formal medical teaching (apart from apprenticeships) commenced only a little time ago in modern Europe; and formal investigation (apart from mere observation or theorising) is of quite recent growth, and is still confined to a very small proportion of medical men. Formal teaching is already being largely superseded by the medical press, and is still poorly paid. Investigation, however, is rapidly taking the first place; nearly all recent medical advances are due to it; it is full of immense potentialities for the whole human race; but, being new, it is the worst paid and least influential of all the branches of medicine. The English-speaking peoples are particularly stupid in this respect; they pay practically nothing for the advantages which they are daily receiving from research, and they are too dull even to recognise their Pasteurs when they possess any, much less to help them. They leave them, like their poets, to live if they can.

Osler shone in all three branches of medicine. He was one of the first to study *Trichina* in man in America, and also the parasites of malaria discovered by Laveran in 1880. Good and strenuous work in these and many other lines; but, as with most doctors, his circumstances soon compelled him to descend to practice and teaching for a livelihood. He held academical posts and professorships at McGill, Philadelphia, Baltimore, and Oxford in succession, and was often in large demand as a consultant, besides his work at hospitals. His textbook, *The Principles and Practice of Medicine*, was first published early in 1892, and had great success, rapidly ousting the older works. The copy which he gave me in 1905 was of the sixth edition, and contains only 1143 pages—though it mentions most of the relevant facts. This condensation is reached by an excellent terse style, and by omitting the diversions of the numerous authors who, when they cannot make a discovery, find it necessary to invent one. Doctors are usually good at observation, but bad at logic; they are easily gulled by pretenders; and many of their tomes are chiefly puffed up with the diet of Milton's sheep. Though he did not argue much, Osler always had a keen eye for literary colitis. On the other hand, like most medical men, he was not at all "quantitative" as I called it, and would chaff me on my mathematical studies of the "epidemical curve." He can rest in peace—we shall go on dying of epidemics in spite of my curve!

REVIEWS

PHYSICS

Relativity and Common Sense. By F. M. Denton, A.C.S.I., M.I.E.E. [Pp. vii + 479.] (Cambridge: at the University Press, 1924. Price 10*s*. 6*d*. net.)

So many books on Relativity, popularly written and otherwise, have already appeared that it must be admitted some excuse is needed for adding still another to this large collection. In this respect the author justifies himself by addressing his remarks in particular to those who have already tackled the subject but have found that their everyday common-sense notions have proved too unyielding to enable them to grasp or appreciate the apparently revolutionary hypotheses on which the theory is founded. The treatment differs in consequence from that usually adopted in that much greater attention is given to the analysis of the new ideas, and in showing that they are not inconsistent with experience, than to the logical development of the theory. The author cannot be reproached with having shirked the difficulties, in fact if anything they are treated in rather too much detail, with the result that there is a considerable amount of repetition. It is felt that a great deal might have been omitted in the earlier part of the book, particularly the rather long discussions on the bases of scientific truth which, however interesting they may be to students of philosophy, are not likely to help those struggling to obtain an insight into the special problems of relativity. As already mentioned, the special and general theories are not treated separately as in most books on the subject, but rather the whole account is concerned principally with the description of phenomena and " events " in the four-dimensional space-time continuum and of the way in which phenomena would be regarded by a universal observer in such a world; the illustrations, in the case of certain simple problems of intersections of world-lines with planes parallel to the different pairs of axes defining the four-dimensional world, are a novel and useful feature of the book and should serve to provide a clearer mental picture of the idea of " interval " in four dimensions. The latter portion of the book appears rather drawn out, and the considerable amount of repetition, in the form of examples, etc., makes reading somewhat wearisome. The equations of the Lorentz Transformation are deduced by a roundabout method requiring more patience than mathematics. The conception of hummocks in the four-dimensional continuum, arising from the presence of gravitational fields, is developed in a simple manner, and their effect on the geometrical relations of the space-time manifold is indicated as simply as possible by means of the general formula for the element of interval ds, without entering any further into the mathematics of the question, which would of course be impossible in a book of this kind. The account given is accurate although rather rambling, and is likely to prove of considerable help to those whom the author has in mind.

J. W. FISHER.

Quatre Conférences sur la Théorie de la Relativité. By A. Einstein. [Pp. 96.] (Paris: Gauthier-Villars et Cie, 1925. Price 12 frs. net.)

THIS book is a French translation from the German of a series of four lectures on the Theory of Relativity delivered by Einstein at Princetown University, and it needs, therefore, no extra recommendation to those interested in the subject and possessing the necessary mathematical knowledge.

The first lecture deals with "Space and Time in Pre-relativistic Physics" and introduces the theory of tensors. The second lecture is on the Special or Restricted Theory of Relativity; while the third and fourth are concerned with the general theory. The third lecture deals with the geometrical foundation of the general theory, together with the general theory of tensors; while the last deals principally with special solutions for the gravitational field together with a discussion of the cosmological problem. Brief mention is made of Weyl's extension of the theory to the electro-magnetic field, but Einstein is of opinion that the correct solution of this important problem has not yet been reached.

J. W. Fisher.

The Production and Measurement of Low Pressures. By F. H. Newman, D.Sc., A.R.C.S., D.I.C., F.Inst.P. [Pp. 192, with 48 figures.] (London: Ernest Benn, Ltd., 1925. Price 16*s.* net.)

During the last twenty years a number of the most fertile discoveries in the domain of physics have been attributable in large measure to advances made in methods for producing high vacua, and, as the importance of this branch of the science has become more and more realised, increasing attention has been afforded it, with the result that it now occupies a position of considerable eminence. Very few attempts, however, have been made to collect the literature of the subject, which is widely scattered among the different technical journals.

The volume under review should therefore be greatly appreciated, for it deals with the subject in a decidedly comprehensive manner, and is phrased in a clear and easy fashion that is well suited to a book largely occupied with detailed description of apparatus. It is thoroughly up-to-date, and contains an appreciable amount of very recent work, but full treatment is also given to the older pumps and gauges, many of which, besides being of historical interest, are still in use for certain special purposes. In the chapter on sorption processes a large amount of useful data will be found, and many of the results are tabulated. This chapter, in view of the importance of sorption phenomena, one would like to see extended, but the nature of the task the author has already completed will be realised when it is stated that in the course of the work there are over two hundred references to original papers. This is a feature of great value, especially to the research worker, who would doubtless like to see these references, which now occur simply as foot-notes, appearing again at the end of the book in the form of a classified bibliography.

Much ground is covered in the treatment given to thermal, chemical, and electrical processes, many of the phenomena described being of exceptional interest, and admitting of no easy theoretical explanation. The last chapter, on exhaust procedure, is rather on the short side, but contains very practical information; in fact, the book is throughout of a definitely practical character, the minimum of space being allocated to theoretical discussion, and even mathematical work is everywhere reduced to the bare outline necessary to indicate methods of proof of formulæ quoted. The volume is well illustrated with good diagrams, and there are a number of convenient tables, in particular those dealing with vapour pressures, pump speeds, and manometer ranges, should be found very serviceable.

Although intended mainly for the physicist and engineer, this book should make a more general appeal on account of the attractive manner in which the many interesting phenomena dealt with are described, while at the same time it affords a thorough introduction to a most fascinating subject.

Ivor Backhurst.

CHEMISTRY

Physico-chemical Evolution. By C. E. GUYE, Professor of Physics at the University of Geneva. [Pp. xii + 172, with 4 diagrams.] (London: Methuen & Co., Ltd. Price 6*s*.)

A COLLECTION of three papers, one on a classification of the sciences, and two on the philosophical aspect of the laws of thermodynamics, considered as statistical principles.

In the first part of the book the author suggests a metaphysical classification of the sciences based on the primordial conceptions of number, space, time, matter, life and thought, a classification which has been rendered possible by the correlation brought about by means of the relativity principle. He indicates the broad lines of advance along which it is probable science will follow.

The title of the book is based on the idea that physico-chemical systems have evolved from the primordial energy or matter along paths trending to more and more probable states. The laws governing the evolution have become more and more complex as the final state is approached, and the course is governed by the increase in entropy which accompanies all physico-chemical change.

The apparent simplicity of the exact physico-chemical laws is due to these being the laws governing large numbers. Science has not yet acquired a very deep insight into the more complex laws governing the individuals of the system. It is possible that the exact physico-chemical laws will not hold rigidly in the minute cellular structure of living beings. The very material fluctuations from the statistical laws occurring when the number of individuals is small may give rise in the living cell to a course of evolution which does not follow exactly the principle of a change to a more probable state.

The method of treatment of the subject is very refreshing, and the conceptions advanced stimulating. Anyone who desires to gain an insight into the general relationships of the sciences is recommended to read this book.

W. E. G.

Physical Chemistry for Students of Medicine. By ALEXANDER FINDLAY, M.A., D.Sc., F.I.C. [Pp. ix + 227.] (London: Longmans, Green & Co., 1924. Price 8*s*. 6*d*. net.)

THOUGH written in the first instance for medical students, this book may be recommended equally well as an introduction to physical chemistry for students of biology in general. The book is divided into twelve chapters, of which the second, fourth, eighth, tenth, and twelfth are respectively entitled "The Aqueous Milieu of the Life-process," "Osmotic Pressure in the Living Organism," "Hydrion," "The Colloidal State," and "The Permeability of the Cell Membrane." From these headings it will be seen that the book does not simply follow the conventional lines of pure physical chemistry, and a perusal of the text will convince the reader that it is full of useful and instructive applications of the principles described. A valuable feature of the book is the inclusion of a number of simple calculations of the type that frequently confront the physiologist or biochemist, such as those connected with osmotic pressures of salt solutions or the conversion of gram equivalents per litre into P_H values, etc., etc. The book is written throughout in a manner likely to develop interest in and to emphasise the significance of physical chemistry as applied to biological problems.

P. H.

Regeneration from a Physico-chemical Viewpoint. By JACQUES LOEB, Member of the Rockefeller Institute for Medical Research. [Pp. ix + 143.] (London: McGraw-Hill Book Co., 1924. Price 10*s*. net.)

THIS book is a record of experiments devised and carried out by the author with his characteristic ingenuity for the purpose of correlating the process of regeneration with the quantity of chemical material. The experiments were carried out in a greenhouse in which no illuminating gas was used, and no smoking allowed, and stress is laid upon the absolute necessity for the success of the experiments of pure air, proper temperature, good illumination, and protection of the plant against parasites. The author's aim has been to provide experimental evidence for what he terms the mass relation—namely, that equal masses of sister leaves produce under equal conditions of illumination, temperature, etc., approximately equal masses of shoots and roots in equal time. The establishment of this relation makes it possible to suggest that the reason why isolation of a leaf leads to regeneration is that the material available in the leaf for growth collects as a result of mutilation in places where it would not have accumulated without mutilation, and this leads to growth in places of the organism where no growth would otherwise have occurred. The process of regeneration is thus revealed as a purely physico-chemical phenomenon leaving, in the author's opinion, " no room for the postulation for guiding principle aside from the purely, physico-chemical forces." The book is divided into two parts, the first correlating mutilation and regeneration on the basis of this mass relation, and the second making an attempt at a similar treatment of the problem of the polar character of regeneration. A number of drawings from nature are incorporated in the text.

P. H.

Book of Knowledge acquired Concerning the Cultivation of Gold. By ABU'L-QUĀSIM MUHAMMAD IBN AHMAD AL-'IRĀQI. Arabic text, edited with a translation and introduction by E. J. HOLMYARD, M.A. [Pp. v + 62 + 51.] (Paris: Paul Geuthner, 1923. Price 30 frs.)

THE alchemists have been the subject of much ridicule and abuse, and from Chaucer to Balzac they have suffered at the hands of literature much the same treatment that the modern chemists endure from the popular press. This is perhaps natural in a world where talk counts for more than deeds and the alchemists, like their lineal descendants, were attacked by the itch to try things. They were, essentially, experimenters in a philistine scholastic world and, as such, laid the foundations of modern chemistry. Their discoveries were not unimportant, but their environment forced them to pretend that they were philosophers in the narrow sense of the term, to throw the cloak of respectability over their base artisan occupation, with the result that much of their work is now unintelligible. Nevertheless, to the chemist who loves his subject, the early period of its history is particularly interesting, and the disentanglement of experimental fact from philosophic jargon a fascinating problem. For these reasons we are grateful that this Arabic manuscript has been made generally available by one who is both a chemist and an Arabic scholar, the more so in view of the few Arabic writings which have been translated, and of the very probable influence they had upon alchemical investigations in Western Europe.

The theory on which the present work is founded is that all metals are essentially the same, differing only by certain accidental properties which can be removed; for example, the imperfection of silver as compared with gold being due to excess of coldness, copper to excess of hotness and dryness. The suggested method of transmutation is based on the biological ideas of absorption of food and of animal reproduction, but metals are supposed to lack the power of rejection of what is not appropriate for them. The book is unusually clear for its type, it shows that the author had considerable chemical knowledge, and gives a vivid picture of the striving for truth of the alchemist burdened with a false premise; one wonders if our own efforts will seem less wrong-headed seven hundred years hence. It is perhaps too much to hope that this book will be read by other than the enthusiast, but we trust that this will not deter the translator and the publisher from fulfilling the prospect, held out in the introduction, of other similar translations, as they are making no mean contribution to learning by rendering these writings available to those who can appreciate them. The reviewer regrets that he is unable to offer any opinion on how closely the translation follows the text.

O. L. B.

The "Chemical Age" Chemical Dictionary. Chemical Terms. [Pp. 158.] (London: Ernest Benn, 1925. Price 16*s.* net.)

This book is designed to give a brief definition or indication of the meaning of the various expressions and names in common use in a branch of science which is clearly indicated in the title. How far it will be of use is probably a matter of opinion, but a competent practitioner of that science should not require definitions of acetylation, acid salts, Boyle's law, flash-point, halogenation, nor indeed of the majority of the terms included, and should know where to find information about more recondite expressions. The uninformed may find some help, although an account of the Nernst Heat Theorem in less than a hundred words is not likely to leave him much wiser. With a book of this kind, it is natural for the reviewer to turn to those subjects in which he is particularly interested. It is unfortunate, therefore, that the section dealing with oximes is so extraordinarily inaccurate; indeed, it is obvious that the writer of the article has not a rudimentary knowledge of the subject; the same may be said of the article on the Beckmann change. There are other minor mistakes, but on the whole the information supplied is accurate.—O. L. B.

Synthetic Organic Compounds. By S. P. Schotz, D.Sc., Tech., F.I.C. [Pp. 412, with 110 illustrations and graphs.] (London: Ernest Benn, 1925. Price 45*s.* net.)

The author of this book does not make its scope very clear either in the title or the preface; it deals, however, with the manufacture of a number of classes of organic compounds which have hitherto been somewhat neglected in English technical literature, although explosives and a few of the commoner intermediates for dyes are included. Other subjects considered are synthetic solvents, perfumes and flavouring agents (under the misleading heading "synthetic aromatic compounds"), antiseptics, sweetening agents, tannins, artificial silk, compounds used in chemical warfare, and plastic masses. The choice is catholic, but on no very obvious plan, and gives an unusual significance to the term "synthetic." Within the limits imposed by the size of the book the author gives a good résumé of the chemical aspect of the manufacture of the various products, with numerous criticisms and suggestions which give an individuality to the work and make it much more valuable than the usual abstract of the patent literature. Very rightly, engineering problems are not entered upon in any detail in the text, but many excellent diagrams of modern plant and its lay-out are included from which the reader can gain a general idea of the mechanical part of the operations.

Judging from those subjects on which the reviewer has specialised knowledge, the information is for the most part reliable and up-to-date; some mistakes, however, occur; for example, on p. 125 tertiarybutylmethylacetophenone is called tertiarybutylmethoxycresol, and on p. 126 trinitrotertiarybutyl-m-cresyl-methyl ether is described as a ketone musk; on p. 263 tetranitroaniline is described as being soluble in the usual solvents, whereas it is decomposed on warming with many of the common organic solvents; on p. 262 it is stated that only 2 : 3 : 4– and 2 : 4 : 5– trinitrotoluenes besides the symmetrical compound have been found in crude T.N.T., whereas Drew has shown that the 2 : 3 : 6– compound is also present, whilst on p. 297 there is some confusion between trisulphide and sulphide.

The printing, diagrams and general get-up of the book are good, but the price places it beyond the reach of many young chemists and students who would find it of interest and use.

O. L. B.

BOTANY

A Textbook of General Botany. By G. M. Smith, J. B. Overton, E. M. Gilbert, R. H. Denniston, G. S. Bryan, and Charles E. Allen. [Pp. x + 407, with 321 figures and 7 plates.] (New York: The Macmillan Co., 1924. Price 16*s*. net.)

Elementary textbooks of Botany, to which class this volume belongs, are now so numerous that they present a wide range both as to their selection of matter and as to its manner of presentation. In the present instance the treatment is extensive rather than intensive.

Nearly half the text is taken up with descriptions of the various plant groups, included amongst which are short chapters on the Bacteria and the Myxomycetes. Anatomy and Physiology are rather cursorily considered, whilst the subject of the soil in relation to the plant is dismissed in less than a page!

Amongst the less usual features may be mentioned the chapters dealing respectively with the economic significance of plants and the geographic distribution of plants in North America.

The book is profusely illustrated with diagrams and photographs which are mostly well chosen. There are also seven plates occupied by portraits of prominent botanists.

The book is one that covers familiar ground in a familiar manner, and if indeed there is rather a lack of individuality in the treatment, probably due to the multiplicity of authors, the text nevertheless contains a great deal of information clearly expressed.
E. J. S.

A Textbook of General Botany for Colleges and Universities. By Richard M. Holman and Wilfred W. Robbins. [Pp. vii + 590, with frontispiece and 374 text figures.] (New York: John Wiley & Sons; London: Chapman & Hall, 1924. Price 20*s*. net.)

This textbook is based on lectures delivered in the University of California to Agricultural and Arts Students. Its object is to set free time that would otherwise be used for formal lectures, and use it for the purpose of answering questions. The authors hold that the agricultural student should be provided with a broad survey of the elementary facts of botany as well as with those aspects of the subject which have a direct bearing on Agricultural processes and problems, and that both the agricultural and the ordinary student will be gainers if economic plants are used, where suitable, for illustrative purposes.

The work is divided into two parts; the first portion deals with the anatomy, physiology, and morphology of the flowering plant. Illustrated historical surveys are given which should heighten the interest of the student. The anatomical part is exceedingly well done, and is profusely illustrated with very carefully selected text figures and diagrams, and the admirable way in which such a difficult subject for the elementary student as secondary growth has been treated might be selected for special mention. Recent work, such as that of Wittstätter and Stoll on Chlorophyll, and of Weaver on the form of the root-systems, etc., are adequately dealt with. Such processes as pruning, budding, and grafting are fully described and illustrated. The drawings of the castor-oil seed, Fig. 208, are inaccurate, and should be replaced.

The second part, which describes the lower groups, includes a general chapter on this Spermatophyta and one on Evolution and Heredity. This portion of the work, although very good, is not quite equal to the first part. The illustrations do not seem to have been selected with such care, *e.g.* no figure is provided of the vegetative shoot or strobilus of selaginella, or of the anatomical structure of the fern stem, and in the chapter on Heredity only one figure is given, viz. one showing leaf-variation in *Artemisia vulgaris*. The

Bryophyta, Algæ and Fungi are very well presented, and due emphasis placed on the economic importance of the Fungi and bacteria. By a slip, it is stated, on p. 363, that the Kelps were formerly believed to be isogamous.

The work is quite an excellent one, and can be strongly recommended to the student. E. M. C.

Plant Life on East Anglian Heaths. Being Observational and Experimental Studies of the Vegetation of Breckland. By E. Pickworth Farrow, M.A., D.Sc. [Pp. x + 106, with 23 plates, containing 46 photographs, and 10 figures in the text.] Cambridge: at the University Press, 1925. Price 7*s.* 6*d.* net.)

Breckland, or the Breck country, which is the region described in this book, is an extremely interesting district. Owing to the comparatively flat nature of the land, to the small rainfall, and the sandy nature of the soil, the conditions under which the vegetation is growing approach very nearly to those of the steppes. The species of plants are not the same as in the continental steppes, but many plants of Central and Eastern European distribution, not met with elsewhere in England, are to be found growing here. Dr. Farrow is of the opinion that some at least of the sand has been blown from the Wash basin, a view which is strengthened by the fact that some few typical dune-plants grow in the region, and that various littoral insects, birds, and shells also occur here. The area has probably never been of much agricultural use, and has been for a long period comparatively free from much direct interference from man. At the present day it is mostly used as rabbit-warrens.

These animals have been proved by Dr. Farrow, by means of a series of simple and ingenious experiments conducted on the field, to exert a very far-reaching influence on the vegetation of the district, and they constitute an important factor in determining the present distribution of the plant communities. The comparative treelessness of the area—woods are only found in the valley-pans where there is plenty of water—has been shown to be due neither to the very low rainfall nor to the quick permeation of the water through the sandy soil, nor even to the low water-table, but mainly to the activity of the rabbits.

Such trees as *Pinus sylvestris* and *Quercus sessiliflora* grow, but only very slowly, in plantations in regions comparatively free from rabbit attacks, and Dr. Farrow's experiments indicate that regeneration would take place were it not for the biotic factor. Indeed, the author holds that this area and other heathy regions in the South Downs were once wooded. The arguments put forward for this view are not decisive, and this part of the book is the least convincing. The rabbits also attack the other members of the vegetation differentially, so that, for example, the Calluna heath degenerates to grass heath; taller plants and inflorescences fall easy victims to their depredations, and some plants are prevented from flowering. These influences cause a continual upsetting of the balance of species, leading to a constant shifting of the dominant type of vegetation.

Other areas have been compared, by the author, with the Breck district in this respect, and the conclusion drawn that the effect of grazing and other animals on the development of successive phases of vegetation is much greater than has been supposed hitherto.

Experiments and observations were also made on the competition between different species of plant in mixed associations and between different pure plant associations in this and other areas. In the case of the former the shade cast by the taller and quicker growing plant is regarded as the most important factor in suppression, except in cases where the biotic factor is the limiting one and the taller plants are more readily destroyed by animals than the smaller. In the case of competing pure plant associations these two opposed agencies have been shown to be the most active in determining the succession of the vegetation, the precise nature of the change depending on the intensity of the attack of the rabbits. Other chapters deal with the effect of wind and blown sand on the vegetation, effect of increased water supply, and the former distribution of Calluna heath and woodlands in England.

The work is of a most interesting and stimulating nature. It is more than adequately illustrated by photographs and diagrams, the former giving a clear idea not only of the vegetation of the area, but also of the nature of the experiments. It should prove of great use to students of plant and animal life, and suggestive to workers on similar problems. The very moderate price is also a recommendation.
E. M. C.

Organic Adaptation to Environment. Edited by M. R. Thorpe. [Pp. xviii + 312, with 34 figures.] (Newhaven: Yale University Press; London: Oxford University Press, 1924. Price 18*s.* net.)

It is now generally recognised that change, whether secular or rapid, is an essential characteristic of both the physical and biotic factors which make up the complex of conditions we term the environment. Adaptation of the organism to this changing habitat, the reciprocal fitness of the individual and its natural surroundings, is at once a necessary qualification for present survival and, by reason of the specialisation involved, a possible handicap to future persistence.

Adaptation to the environment thus presents itself in one of two guises, according as it is viewed from the static or dynamic standpoint. In the one the individual at a given phase, usually maturity, is apprehended in relation to its surroundings at a given time, whilst in the other we see the ordered sequence of ontogenetic change in relation to a relatively stable habitat, or the interplay of changing environmental conditions and the phylogenetic development of the race.

This last aspect is admirably presented in these pages by Prof. C. O. Dunbar, who gives a lucid account of the progressive coiling of the Cephalopod shell probably in relation to increasing buoyancy—an hypothesis supported by the association of heavy ballasted types of shell with a straight form. As for the "gerontic" types, these are regarded as correlated with the assumption of a vertical rest position, in place of the horizontal one characteristic of their ancestors. Again, amongst the Ammonites, the phylogenetic succession, from types with a simple suture in the Palæozoic to types with such highly complex sutures as *Phylloceras* in the Jurassic, can be visualised as progressive adaptations to the increased pressures accompanying an increased depth range.

The environment itself is the subject of a chapter by Prof. G. E. Nichols, who treats of it from the botanical standpoint. The factors are grouped as Climatic, Physiographic, Biotic, Anthropic (Influence of Man), and Pyric (Influence of Fire): a classification in which the grouping of Topographic and Edaphic factors together is, we venture to think, as undesirable as the separation of the effects of Man from the other Biotic factors.

In its effect on internal parasites, as for example the Tapeworms, the environment is conceived by Prof. Petrunkevitch as a stabilising factor which "protects the average from the dangers of an escape from a happy mediocrity." On the other hand, there appears to be no evidence that new species of internal parasites have arisen by the selection of favourable mutations.

The problem as presented by the Protozoa is dealt with by Prof. Woodruff, who shows that the unicellular organism, despite the limitations that the simplicity of its construction imposes, presents the same kind if not the same degree of adaptability as the Metazoan organism, whether to the physico-chemical forces of the inanimate world or the conditions of a biotic environment.

The fossil record in its botanical aspect is presented by Prof. Wieland as a story of resistance by the vegetable organism to the impress of the environment. He postulates a more or less uniform and slow rate in the production of new types, and in a somewhat speculative estimate of the numerical frequency of species in past geological epochs Prof. Wieland visualises the plant population throughout the ages as a vast inverted cone of which the cross section at any period is proportional to the number of the then existing species. One may, however, hazard the suggestion that the dominance and abrupt decline of successive plant and animal groups in past ages indicate the possibility that organic life as a whole was rather a series of inverted but truncated cones.

The relation of environment to the origin of new types is discussed from the genetical standpoint by Prof. W. R. Coe, who rightly emphasises the importance of recognising that the visible characters of an organism are the product of both heredity and environment. Whilst mutations may possibly be responsible for the origin of all new types, Prof. Coe admits we are still in complete ignorance as to their cause. But in expressing the view that environment has nothing to do with their production he is perhaps less prudent, for no effect is produced without a cause and, however indirect, the changes in the genes must ultimately be connected with changes in the internal environment, and these in turn with changes in the external. This attitude is perhaps not unconnected with the dogma that there is something fundamentally different between germ-plasm and soma, a view to which many zoologists so fondly cling despite the growing evidence that in animals as well as in plants the unspecialised cells of the soma are the potential equivalents of germ cells from which germinal tissue may itself originate.

The parallelism in evolution shown in animals by the frequency of albino varieties of totally unrelated types or the close resemblance in the wing pattern of butterflies belonging to distinct genera resulting in the phenomenon generally designated mimicry, or again the striking instances among plants to which attention has been drawn by Prof. Paviloff—all these bear witness to the interaction of corresponding forces.

Prof. R. S. Lull contributes a survey of the Dinosaurs and shows how the variety of their structure can mainly be correlated with the climatic changes in their habitats and the divergences in their habits; whilst in the final chapter Prof. Huntingdon shows how the characteristics of human races have probably been determined in the main by the peculiarities of their respective environments.

It will be realised that the successive chapters are in the nature of separate essays only linked together by their central theme; but the very diversity of the premises on which they are based and the variety of treatments which the subject-matter receives, render the volume of very real interest to the student of philosophical biology.

E. J. Salisbury.

Plant Anatomy. By Prof. William Chase Stevens. Fourth Edition. [Pp. xiv. + 398, with 155 illustrations.] (London: J. & A. Churchill, 1924. Price 15*s.* net.)

This is a somewhat elementary account of plant structure in which the reader will probably experience some surprise both with respect to inclusions and omissions. For example, several pages are occupied with speculation on the phylogeny of the vascular cylinder, but the reader is left almost entirely in the dark as to the facts respecting the mode of transition from the anatomical structure of the root to that of the stem. Whilst root structure and the mode of origin of lateral roots receive but scanty attention and the description of stomatal organisation is of quite an elementary character, the specialised leaf structure of *Polytrichum* and the very abnormal axial organisation of *Serjania* are both described and figured.

Noteworthy features are the section of forty-four pages devoted to an alphabetic guide to the microchemical recognition of the commoner plant products, and the chapter of forty-five pages on reagents.

The fact that this volume is now in its fourth edition bears witness to the demand for information on this subject; nevertheless one cannot but realise that, throughout the text, adequate advantage has not been taken of the opportunities for revision which these successive editions have afforded. Even the illustrations are not entirely free from error, as shown by the diagram of the epidermis of an oak leaf, in which the stomata are portrayed as though similarly constructed to those of a Bryophytic sporophyte.

It is much to be regretted that the inaccuracies in the text, though often of a relatively trivial character, materially detract from the value of a book dealing with an aspect of botany to which a reliable guide is a desideratum.

E. J. S.

ZOOLOGY

Outlines of Economic Zoology. By ALBERT M. REESE, Ph.D. [Pp. xix + 318, with 194 illustrations.] (Philadelphia: P. Blakiston's Son & Co., 1924. Price 2.50 $.)

THIS book presents a very varied assortment of information about animals, regarded from the point of view of their helpfulness or harmfulness to human activities. We are told that certain " very large pieces [of coral] are much in demand in China for the official buttons of the mandarins "; that " it is estimated that in Paris alone 200,000,000 snails are consumed in a season, September to April," but that " they are a delicacy, not a staple article of food, like beef." A further tribute is paid to French cooking on p. 141, where it is stated that, owing to the scarcity of the diamond-back terrapin, " the French chefs are now said to be trying to induce the proprietors of the hotels to purchase the cheaper terrapin, promising that when they are through with cooking them the guests will not know the difference."

But the book also has its serious side. Every lover of animals will deplore the terrible depredations done by the senseless destruction often of rare and interesting species without the smallest economic justification. To quote one among many examples: on p. 171 it is stated that " Besides being killed for their hides, the alligators have been destroyed by the thousands merely for wanton sport, so that in 1902 it was estimated their numbers in Florida and Louisiana were less than one-fifth of what they were twenty years before that time, and, unless steps are taken to prevent it, the alligator hide, as an article of commerce, may cease to exist in our Southern States." In the succeeding paragraph other consequences are mentioned: " It has been claimed that the destruction of the alligator has allowed the cane-rat and muskrat to increase to a serious extent, the former doing great damage to crops, the latter often injuring the levees to a dangerous extent."

Very interesting accounts are given of the efforts of the United States Bureau of Fisheries and of Agriculture to stop the extermination of important food animals, and to curtail the depredations of harmful ones. The book is copiously and well illustrated, and can be heartily recommended, more perhaps to the general reader than to the professed student, because it is desirable that the widest publicity should be given to the dangers of ignorant destruction of animals, and to the wonderful success that has followed the careful study of the habits of those animals whose artificial cultivation has been made necessary by such destruction. From both the scientific and economic point of view the accounts of the rearing of sponges, oysters, lobsters, various species of fishes, and terrapins, make very impressive reading. The chapters on birds and mammals, which together occupy about a third of the book, are full of interesting information told in a way sufficiently free from technicalities to appeal to the general reader. J. H. W.

The Internal Secretions of the Sex Glands. By ALEXANDER LIPSCHÜTZ, M.D. [Pp. xviii + 513, with 142 illustrations.] (Cambridge: W. Heffer & Sons, 1924. Price 21*s*. net.)

ALTHOUGH one of the youngest branches of physiology, the study of the internal secretions of the sex glands has already accumulated a vast and conflicting literature. English readers will therefore welcome this translation by the author himself, of Prof. Lipschütz's book, *Die Pubertätsdrüse und ihre Wirkung*. The present edition is, however, more than a translation of his former book, for since 1918 so many important new facts have come to light that the book has been entirely rewritten to include them.

The subject is introduced very appropriately by a discussion in the first chapter on the meaning to be attached to the terms "sexual dimorphism" and "secondary sexual characters." The author points out that the classification into primary, secondary, and tertiary characters, in so far as it implies a genetic dependence of one upon another, must rest upon a positive experimental basis, and it is with the discussion of this basis that Prof. Lipschütz's book is concerned.

It might at first sight be supposed that the sex cells are themselves the real primary characters, but in truth the problem is greatly complicated by the fact that the development of the gonads is also under the influence of the thyroid, adrenals, and hypophysis cerebri. Some fixed point must, however, be taken, at least provisionally, as a starting-point for investigation, and Prof. Lipschütz takes the sexual gland itself as his "relatively quiescent basis," and proceeds to inquire how far the other sexual characters are dependent genetically upon it. That being determined, it is then possible to ask how far other parts of the organism are capable of influencing these characters; on the one hand, indirectly, by their action on the sex gland, and on the other hand directly on the sexual characters.

The second chapter is accordingly devoted to the effects of removal of the sexual gland in the various groups of the animal kingdom, and Chapter II deals with the various ways in which the influence of the sexual gland, through internal secretions, has been investigated: by transplantation, feeding, and injection. In the two following chapters the evidence bearing on the parts of the sexual glands responsible for the production of these secretions is reviewed in the two sexes. In the male it is concluded on the existing evidence that the interstitial cells of the testis are necessary for the endocrine activity of the testis, and that there is no proof that the other elements, the seminiferous tubules, are capable of such an activity independently of the interstitial cells. In the female, at least in mammals, the author concludes that it is "highly probable" that the cells of the membrana granulosa and theca interna both take part in the production of the internal secretion of the ovary.

The question next arises: How far are the endocrine products of the two gonads "sex specific'? To this question Chapter VI is devoted, and includes a review of the celebrated experiments of Steinach on mammals, from which the conclusion that "one and the same organ or tissue reacts in a different manner to the hormones of the gonad according to the sex of the latter" can, in the author's opinion, be most confidently drawn. The results obtained from birds and amphibia are less conclusive, and no effect has so far been obtained on Arthropods from the transplantation of gonads into castrated members of the opposite sex.

The bulk of the rest of the book is devoted to the subject of "intersexuality," two fundamental questions being considered: *first*, "whether combination of male and female somatic sex characters is really caused by simultaneous presence of gonads of both sexes in the same individual. And *secondly*, if the first question is to be answered in a positive sense, whether such an "hormonic intersexuality" . . . is caused by male and female endocrine cells, other than generative cells of any stage, simultaneously functioning in the same organism. Prof. Lipschütz considers that the first question can be answered in the affirmative on the basis of the transplantation experiments of recent years, especially those of Steinach and Sand. The second question is left open, for there are various objections urged against Steinach's interpretation that pseudohermaphrodites really contain endocrine cells of both sexes.

A specially admirable feature of this book, which strikes the reader on every page, is the very clear and unbiased manner in which the author handles the many complex and controversial problems with which this subject bristles. His treatment is scientific in the best sense of that much-abused term. A little too much weight is perhaps given to some rather isolated experiments, for example, to Minoura's transplantations of fowl gonads on to the allanto-chorionic membranes of chicks, which are mentioned no fewer than ten times. Since this book was published these experiments have been repeated with, it is claimed, totally negative results.[1]

In the discussion of homosexuality in man, and "psychosexual" behaviour in general, the problem is regarded from a purely physical point of view, the possibility of autonomous psychical factors not being considered. This will perhaps account for the conflicting results recorded of purely surgical attempts to treat this condition. So long as human behaviour is regarded exclusively in this way, and such agents as internal secretions are considered as "causes" of behaviour, similar results will continue to attend our efforts to relieve the aberrations of the human mind. J. H. W.

A General Text of Entomology. By A. D. Imms, M.A., D.Sc. [Pp. x + 698, with 607 illustrations.] (London: Methuen & Co., 1925. Price 36*s*. net.)

The earliest precise records of observations on insects are those of Aristotle in the *Historia Animalium*. From that period until about the fifteenth century, there appears to have been very few contributions in this branch of Natural History, although there is evidence that in Arab culture from the ninth to the twelfth century, the *Historia Animalium* had some influence, especially in relation to bee culture and the silk-worm industry. In the early part of the thirteenth century, Alberto revived interest in the *Historia Animalium*, but it was not until the development of the spirit of inquiry in Natural History, which began in Italy in the early part of the sixteenth century and rapidly spread over Europe, that any further noteworthy observations on insects were made. From that time several observers made important contributions to the development of the subject, namely, Edward Wooton, Thomas Moufet, Redi, Malpighi, Leuwenhoeck, and Swammerdam, to mention only a few. During the eighteenth century many important treatises appeared, written by authors whose names are familiar to the student of entomology, namely Frisch, Reaumur, De Geer, Fabricius, Linnæus, etc. With an ever-increasing number of enthusiastic observers and collectors, a flood of literature dealing with insects appeared during the nineteenth century. Of recent years the influence of the economic aspect of entomology has resulted in a rapid expansion of our knowledge, and this up-to-date general textbook by Dr. Imms will be welcomed by all interested in the subject.

The author has freely availed himself of the facts made known during recent years, thus bringing the subject into line with the requirements of the present-day student, research worker, and teacher. The subject-matter, which is divided into three parts, is of necessity greatly condensed, and one is impressed with the wealth of facts which are gathered together in the volume. The list of references given at the end of each chapter is a useful feature of the book. The illustrations, 607 in number, several of which are original, are well selected and clearly reproduced and the fact that common species have in many cases been chosen for illustration of anatomical and other details will be valuable to the teacher. Part I (pp. 1–156) deals with the external and internal anatomy, physiology, and the various organs and systems of the body. Part II (pp. 157–89) deals with development and metamorphosis. Part III (pp. 199–667) is devoted to the orders of insects. Short diagnostic characters of each order are given, followed by an account of the chief features of the morphology and anatomy and a short account of the different families, keys having been given in most cases.

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[1] A. W. Greenwood, *Brit. Journ. Exp. Biology*, vol. ii, p. 165.

The classification adopted comprises twenty-three orders, the Protura (order 2), being placed next after the Thysanura, and the recent order Zoraptera as a sub-order of the Psocoptera. It would appear, from the context of p. 290, that the spelling of the ordinal name Anoplura has been overlooked in proof-reading, as also the transposition of meso-and metathorax in lines 5 and 6 on p. 592. One or two minor points have been overlooked, *e.g.* 607 (title-page), Phthirus, *P. pubis* Linn. (p. 296). There is an author's index and an efficient general index.

An important feature of the book is the presentation of a large number of facts made known during recent years; and a short introductory chapter dealing with the history of Entomology would have been fitting as giving the student a general perspective of the progress made in the subject.

The mass of information which has been collected, and the evident care and experienced judgment shown in the clear and concise manner in which the facts are presented, should ensure a place for this volume on the bookshelf of everyone interested in entomology. The price, at 36*s*., is reasonable.

JAMES DAVIDSON.

Animals in the Making: An Introduction to the Study of Development. By J. A. DELL, M.Sc. [Pp. xii + 115, with 31 figures.] (London: G. Bell & Sons, 1925. Price 2*s*. 6*d*. net.)

APART from a couple of chapters on lenses and microscopes this text is an elementary study of the biological processes of reproduction. It is a healthy sign that schools are at last seriously considering the need to teach the elementary principles of biology and to aim at a clean and healthy understanding of sex. The fact, however, in this case that chapters on lenses and microscopes are introduced into this book, instead of into a preliminary course of general biology, suggests that this part of the subject is being given undue prominence instead of naturally taking its place in a general course of biological study. Some of the arguments used are not appropriate.

W. C. B.

Marine Structures, their Deterioration and Preservation. By W. G. ATWOOD and A. A. JOHNSON. [Pp. 534 + 169 figures.] Published by the National Research Council, Washington, D.C., 1924.

ONE is sometimes depressed by the conviction that a huge fraction of the material fabric of our modern industrial civilisation is so transitory in its nature. We regret the deterioration of noble structures like St. Paul's Cathedral, the Palace of Westminster, and Waterloo Bridge. We have not the will to build similar works, and so we witness with mixed feelings their ultimate decrepitude. On the other hand we see, without regret, so much more of the structure, in stone, brick and lime, of our nineteenth-century factory-made England, on its rapid way to the scrap-heaps and we hope that our children and grandchildren may do better.

The book under notice is a thoroughly practical one. It does not deal with sentimental considerations of any kind; it has as its concern the endurance of harbour works, and it recognises that permanence is not a result to be sought. All such structures become obsolescent, and the time comes when it is expedient to replace them. The materials need not be such as will endure indefinitely, but it must be rather a nuisance when they do not last their period of usefulness—or, at least, profit. What the American marine engineer wants is knowledge that will enable him, on the one hand, to predict the period of usefulness, and, on the other, to choose materials that will just endure throughout that period.

Such materials are stonework, concrete, wood piling, metal posts, or other structures. All have proved to be less enduring than is desirable. Wood and concrete are destroyed ultimately by marine crustaceans and molluscs, and metal work corrodes. The properties of wood and metal are well known, but less is known with respect to cement-materials. There is Roman cement which has withstood centuries, and Smeaton made use of cement in the construction of the Eddystone Lighthouse that has endured for over a century. It is remarkable that in neither case was the chemistry of the compounds known, yet they have been more permanent than are modern concretes, in spite of the opportunities for present-day industrial and scientific research.

The book before us is the Report prepared by a Committee on Piling Investigations appointed by the Division of Engineering and Industrial Research of the American National Research Council. It is not a completed study of the modes of deterioration, and the best measures designed to minimise this, in the cases of marine structures. Much investigation is still suggested by the Report, which is mainly the account of the very numerous tests made on the Atlantic, Caribbean, and Pacific coasts of America. It includes a good biological survey in which the ecology of the marine boring animals has been very well done. For the rest, the Report includes very full details of the experimental and observational work of the Committee, and it is a compilation of results, stated clearly and very fully, and bringing together data which are certain to be of very great value to all members of the engineering profession who may have to undertake harbour works and have the desire to investigate the materials that they use. A very large part of the book deals with the results of various methods of protecting wood and metal structures that are placed beneath the sea. These results are probably of very considerable value.

J. J.

Corals and Coral Reefs: An Introduction to the Study of Recent Corals. By PROF. SYDNEY J. HICKSON. Publications of the University of Manchester; Biological Series, No. IV. [Pp. xiv + 257, with 110 illustrations.] (Manchester: at the University Press; and London: Longmans, Green & Co., 1924. Price 25*s.* net.)

THE problem of the mode of origin of coral reefs in the various oceans of the world is one that has still to be laboriously investigated. The time was, after the publication of Darwin's observations, when what was regarded as a fairly complete theory had been made. Then came renewed work over a rather greater region than that actually seen by Darwin, and many difficulties became apparent. In particular John Murray, after the return of the *Challenger* Expedition, raised such difficulties and made a new theory which differed notably from that of Darwin. There was much controversy, and then general opinion followed Murray. Other expeditions and observers made new observations; the whole question became very complicated, and it was thought that experiment alone would clear up the matter. So there was the famous Funafuti Expedition in the course of which a deep boring was made on what was thought to be a very typical Pacific coral atoll. The results were inconclusive on thorough discussion and did not settle the question of coral reef formation in the least. At present the opinion of both geologists and zoologists appears to incline towards the Darwinian hypothesis rather than that of Murray.

The problem has two aspects—one for the biologist and the other for the geologist. It is probable that no generally applicable explanations suffice for the coral areas of the Red Sea, the Indian Ocean, and the Pacific. In each case there are probably rather different modes of origin. In each case an absolutely essential investigation must be that of the movements of the ocean bottom, or of the floor of the continental shelf. In many regions it is not clearly known whether that movement is one of elevation or depression. The attentive study of such evidences as we have has only been made well in a few places (as, for instance, by Crossland in the Soudanese Red Sea Coast). This work must be greatly extended. In oceanic regions, as in the Central Pacific, the problem is much more difficult, and obviously it links up with geophysical investigation. The recent work of Harold Jeffreys, for instance, is relevant to the question of coral reef formation.

On the other hand, the coral reefs are the work of animal organisms, and the question becomes one of the ecology of these creatures. Little work of this kind has been done, but there are noteworthy contributions by Waylano Vaughan and Drew, for instances, and these indicate the interest of renewed biological research. From this latter point of view Prof. Hickson's book comes to supply an obvious want, for it deals, in a highly interesting way, with the morphology of the coral-building animals and plants. Not only the geologist, but also any zoologist who takes up this investigation, will find the book of extraordinary value. It is also one which will be read with advantage by the general zoological student, and it is so well done that one rejoices in its publication. The manner is pleasant, and very careful at the same time. There are photographs of most of the prominent species, and these alone give distinction to the book. It is rare indeed that a book on any part of zoology has been so beautifully illustrated. There are few college or even good school libraries that can dispense with the book, and it may be confidently recommended.

J. J.

Lamark-Darwinism and Dental Disease. By ORAN STARR, D.D.S., L.D.S. [Pp. xiv + 319, with 10 illustrations and 2 diagrams.] (London: George Routledge & Sons, 1925. Price 21*s*. net.)

ANY serious attempt to investigate the causes of the appalling and widespread incidence at the present time of dental disease in civilised man must be welcomed, not only by the medical and dental professions, but by the lay public as well. Dr. Starr has made a study of the subject from an entirely new point of view—that of evolution. Rather more than half the book discusses the laws of evolution, entirely apart from dental questions, and the author endeavours to show that, after life was spontaneously evolved from our chemical ancestors, its development has followed Lamarck's hypothesis that acquired characteristics can be and are transmitted to offspring. Darwin's law of natural selection, although not inoperative, takes a very secondary place. " There is chance in Natural Selection. There is physiology and anatomy in Lamarckism. Chance favours the best, but the best is built by the physiological action of Lamarckism."

Coming to the question of dental disease, he says that the teeth of civilised man are rapidly degenerating, that this degeneration is due to a softness of the dental structures acquired by lack of proper function, and that this softness is being transmitted to subsequent generations.

It is taken as certain that the body is capable of increasing or diminishing the quantity of lime salts in the teeth; but this is surely at present a point very much open to question, and still awaits clear proof. Dr. Starr disapproves of the theory of vitamins, and substitutes one of " Ancestropabule," but with his conclusion that the essential factor in the prevention of dental disease is to be found in a correct diet no one will disagree who has given any serious thought to the problem.

The cooking of practically all foods destroys their fibrous character which compels proper mastication, and reduces them to a pulpy, semi-fluid condition in which they cling to the surfaces of the teeth, where they remain long enough to form those acid products of fermentation which initiate dental caries.

Whether or not the argument from Lamarck-Darwinism is sound, it is right to emphasise the tremendous importance of instructing the rising generation in as much as we do know of the causes of dental disease, and to insist on the use of as much uncooked fruit and vegetables as possible.

J. A. S. W.

Genetics and Eugenics. A Textbook for Students of Biology and a Reference Book for Animal and Plant Breeders. By W. E. Castle. [Pp. viii + 434.] (Oxford: at the University Press, 1924. Price 12*s.* 6*d.* net.)

The popularity of this book in America is evidenced by the fact that we have now the third edition. It would be better described by such a title as a *Textbook of Mendelian Genetics.* As far as Part IV, "Eugenics," is concerned, it can only be described as surprisingly inadequate. Blunders of interpretation occur over and over again. Thus when discussing Galton's Law of Regression, Prof. Castle writes:

"Johannsen has shown, as regards the size of beans, that regression is due to a lack of agreement between somatic and genetic variations, the latter being more conservative, and that when selection is made within a line, pure genetically, no regression occurs. Davenport confirms this view in the case of human stature, showing that the children of parents genetically pure for tall stature do not regress towards mediocrity, as Galton supposed all classes of a population to do. Galton's law of ancestral heredity and his principle of regression are now chiefly of historical interest, but it is well to keep them in mind when generalisations based on similar reasoning are brought forward" (p. 295).

Now, it is difficult to be patient in view of such a combination of misstatements. Johannsen's theory of pure lines is certainly not demonstrated by his beans, for his own observations show that the maternal bean is more than twice as influential as the grandmaternal bean on the offspring, which contradicts the entire hypothesis of the pure line as applied to beans! Further, Johannsen represented his maternal plant by a *single* bean, but, an average bean weighing 400 mg., the single bean would represent a plant average with a degree of accuracy of ± 50 mg. Under such circumstances how can we tell whether a plant from the observation of a single seed is to be classed as a small weighted-seed or a heavy weighted-seed plant? The whole bean investigation was really idle. We are next told that Davenport has demonstrated the "pure-line" theory for stature. Now, a man's ancestors in the tenth generation represent a very fair sample of the whole population of the country in which he is born. In any European country like Great Britain, much more so in America, this means that he is a hybrid from many races of racially different stature. How is it possible to tell that a human family, which can be measured in scarcely ever more than three, and generally only two, generations, is of "pure line" for stature? Is it not arguing in a circle, and picking out those families you find are "tall" and calling them a "pure line"? You would have to wait twenty years to ascertain whether the last generation would breed true, and if they did not, you would get over your difficulties by asserting that they had married out of the "pure line"! Prof. Castle in the paragraph cited states that Galton supposed all classes of the population to regress towards mediocrity, *but he leaves out Galton's hypothesis that the community mates at random.* The law of ancestral heredity directly demonstrates that if like mates with like—or if a "pure line" could be established—there would be no regression at all! This is precisely what the "pure-line" theory propounds, but it is demonstrated neither by Johannsen's beans nor by Davenport's data as to stature. It is somewhat amusing, therefore, after a paragraph which shows that the author has not critically examined either Johannsen, Davenport, or Galton, to be told that the law of ancestral heredity and the principle of regression are now of historical interest.

On pages 338–9 we have the usual Mendelian programme of what are recessive characters in human heredity, embracing, of course, feeble-mindedness, and later, on the basis of Davenport and Weeks's paper, epilepsy is included in the same category. There is not a word to show that both these statements have met with most destructive criticism. If we turn from man to the lower animals, Prof. Castle gives the standardised views in the standardised way, but those who have spent many years of life over one single species will find it very difficult to accept much of the unit-character classification provided (*e.g.* for dogs, p. 182). It is not possible to express piebaldism in mammals as a unit character; every grade of piebaldism will be found within definite limits to be inherited. And that is the general result of any study of a Mendelian unit-character—the more closely we investigate it, the more we endeavour to pass from broad categories to fine measures, the less truly descriptive of Nature's inner mechanism does it appear. Her secrets are not writ so large that they can be read by the unaided eye, and that is what in most cases the propounders of unit-characters are endeavouring to do. Prof. Castle's book is less cautious in its statements than Prof. Bateson's *Mendel's Principles of Heredity*, and will hardly supplant the latter in this country; and it is certainly inferior in treatment and breadth of topics to Richard Goldschmidt's *Einführung in die Vererbungswissenschaft*, or for human heredity treated from the Mendelian standpoint to Baur, Lenz, and Fischer's *Menschliche Erblichkeitslehre*, which at any rate, if it be dogmatic, is certainly comprehensive as far as man is concerned. One feels after reading the latter that either nothing—or everything—is left to be said, and it is a minor sense of the like insecurity which one reaches on perusing *Genetics and Eugenics*. If one may personify "Nature," how she must enjoy the attempts of some of her ardent lovers to unriddle her character!

ANTHROPOLOGY

Fossil Man in Spain. By PROF. HUGO OBERMAIER, translated by CHRISTINE D. MATTHEW, and published for the Hispanic Society of America. [Pp. xxviii + 495, with 158 illustrations.] (Newhaven: Yale University Press; London: Oxford University Press, 1924. Price 23*s*. net.)

THE honour of being the pioneers who developed the theories on which the modern science of prehistory is based, theories which have been so fully justified by later discoveries, may justly be claimed for Frenchmen—for Boucher de Perthes, Edouard Lartet, and Gabrielle de Mortillet. It has been on French soil and by French workers that the most careful and extensive investigations have been chiefly carried out. The concentration on a comparatively small area of the south of France, which was a favourite hunting-ground of Palæolithic man, has perhaps given a somewhat distorted picture of the prehistoric history of Europe as a whole. It is only within recent years that it has been fully realised that the successions of cultures which were established principally from excavations in the Dordogne and Charente are only found identically the same at sites within a very limited area. Comparison with the differing cultural histories of neighbouring regions of Europe promises to modify the ideas of earlier writers. After meridional France, the north of Spain is the ground which has been most completely and carefully surveyed, and a comprehensive account of the work carried out there presented by the greatest living authority is a book of prime importance to the prehistorian. Prof. Hugo Obermaier's *El Hombre Fósil* was first published in 1916. The present translation is of the revised Spanish text brought up to date by the author.

Fossil Man in Spain is not restricted in its scope to the Iberian Peninsula. The first five chapters present the main findings of general prehistory. They are followed by a summarised account of the excavations of all the Palæolithic stations of any importance that have been discovered in Spain and Portugal, and succeeding chapters deal with chronology, art, and human remains from the more general standpoint. Detailed accounts of many of the Spanish sites have not yet been published and the majority have only been explored within the last ten years. The north is far better known than other regions. From a comparative study of the cultures represented in all the hitherto explored sites the writer concludes that the country was a connecting link between the civilisations of France and the so-called Pre-Caspian and Caspian stages of North Africa. The blending of the two industries is found at least as early as Mousterian times and it can be traced without intermission down to the end of the Old Stone Age.

An interesting account is given in chapter vii of the " mobiliary " and mural art of Late Palæolithic times. From that point of view the caves of Northern Spain stand pre-eminent, the cave-drawings being finer in execution and more numerous than those of any other region of the world. It is not unreasonable to concede to their artificers a higher cultural level than that attained by almost all present-day primitive peoples.

As regards the geological history of Quaternary times, the author accepts the four glacial stages of Penck and Brückner, and from a personal study he was able to apply that Alpine classification to the French Pyrenees. But whereas Penck originally synchronised the cold Mousterian epoch with the third (Riss) Glacial Stage, Obermaier would assign it to the last (Würm), and that view has also been accepted to-day by most authorities.

The writer's attitude to the much-disputed question of eoliths has apparently changed recently. The first chapter is devoted to the question, and it concludes with the statement that the existence of Tertiary man cannot be proved as yet by any such evidence. But on pages 39 and 40 the flints recently discovered with evidences of fire at Foxhull are described as the first evidence we have of the existence of man at the end of the Tertiary. The obviously additional account of the most recent discoveries of Reid Moir would have been placed more appositely in chapter i.

Chapter ix deals with the skeletal remains of Palæolithic man, and it is little more than a catalogue of all the authenticated and supposed spurious specimens. There are several in the list discovered in Spain which will be of considerable interest to the physical anthropologist, but of which no detailed accounts are as yet available. Obermaier inclines to the unusual view that many of the skeletons discovered in America for which Lehmann Nitsche has claimed a Palæolithic age are authentic. He supposes that the scepticism with which they have been treated by most authorities is exaggerated.

Fossil Man in Spain is fully illustrated. Many of the plates are reproductions of remarkable examples of Late Palæolithic mural art which are not to be found in other textbooks of prehistory. The bibliographies for the separate chapters provide ample references to specialised monographs in several languages, and they will prove invaluable to the foreign student desirous of obtaining a first-hand acquaintance with the Spanish writings. The English-speaking reader is indebted to Miss Matthew and to the Hispanic Society of America for an excellent translation of a classical treatise which was previously known to them rather by name and reputation than by first-hand acquaintance.

B.

The Races of Man and their Distribution. By A. C. HADDON, Sc.D., F.R.S. [Pp. viii + 184, with 10 plates.] (Cambridge: at the University Press. Price 6*s*. net.)

IN a popular exposition of a scientific subject we may naturally expect to find more dogmatic statements than a specialist would make to his fellow-workers. It is difficult to present a concise and popular account of the work already accomplished in any specialised branch of knowledge and to give, at the same time, a just idea of the uncertainty which shrouds the region between the known and the unknown. Prof. Haddon had evidently decided to ignore almost entirely the latter aspect of the question when writing the second and revised edition of his textbook, *The Races of Man*. It purports to give a complete classification of the existing and of many extinct races of man, and is likely to foster, in the mind of the general reader, the illusion that that problem has already been solved—in general outline, at any rate—to the complete satisfaction of those who have devoted themselves to the study of that particular subject.

The classification adopted is said to be based almost entirely on physical characters—secondary importance only being given to the inferences to be drawn from archæological and philological research—and a short account of them is given in the first section of the book. They consist mainly of the "character of the hair, skin-colour, stature, form of the head, the characters of the face, nose, and eyes." Little attention seems to have been paid to craniological and other osteological characters which cannot be measured on the living. Free use is made of the barbarous nomenclature which obscures the all-important conception of the continuity of the distributions of all the observed characters. Surely that could have been dispensed with in a book which is not intended to be highly technical.

In the second section there is an arrangement of the three main divisions of mankind which Prof. Haddon accepts—the Ulotrichi, Cymotrichi, and Leiotrichi—and their various sub-groups. That is followed by short physical descriptions of the principal races which make up those sub-groups and the geographical distribution of the races. Little credence can be given to the sections dealing with prehistoric races and their connections with existing types, but the summaries of the anthropometric characters of modern races should be valuable to the student.

In the third section of the book, which comprises the greater part of it, there is given a sketch of the probable racial history of the main areas of the world. Such a sketch forms a fitting introduction to world-history and will be of interest to the general reader. It is perhaps inevitable that even an abridged account of such a vast subject should abound in statements which are open to criticism. It must suffice now to cite a few such relating to our own islands. Can we really "accept it as established that a type which occurs in the Plynlymon moorland and elsewhere in Wales is directly descended from the Aurignacian Eurafrican race" (p. 77)? What evidence is there that three *distinct* brachycephic races had invaded England before the end of the Bronze Age, and by what criterion—accepting a method of classification which is to be based on bodily characters alone—can they be judged distinct (pp. 78 and 79)? And of what sort is the evidence "that in the last hundred or two hundred years the average cephalic index of Londoners has risen from 77 to 79" (p. 83)?

In the last section of *The Races of Man* Prof. Haddon gives a general summary and notices of various recent attempts that have been made to elucidate the mechanism of the evolution of man. He does not commit himself to any particular theory, but gives a fair impression of the uncertainty which is at present attached to all such problems.

Prof. Haddon's book is an essay to provide a complete classification of the races of man. It is perhaps a fair and moderate statement of the methods and results of a contemporary school of British anthropologists. It is clear that those methods are entirely opposed to the ones employed by other schools of anthropologists, and that they must inevitably lead to widely different results.

There are several excellent photographs of representatives of primitive peoples, a diagram illustrating the supposed connections between the main families of races, and a short but useful bibliography. B.

The Home of an Eastern Clan. A Study of the Palaungs of the Shan States. By Mrs. Leslie Milne. [Pp. viii + 428, with 20 plates.] (Oxford : at the Clarendon Press, 1924. Price 16*s*. net.)

The Palaungs inhabit, for the most part, the hill country in the Shan States of Upper Burmah. Their chief industry is tea-growing, and as yet they have had little contact with European civilisation. They are distinguished in many ways from the more numerous Shan tribes adjoining their country. After studying the language and customs of that latter people, Mrs. Milne turned her attention to the Palaungs in 1911 ; and before that time no one had seriously studied their language and culture. In *The Home of an Eastern Clan* a detailed and first-hand account is given of the psychology, religion, and social customs of the Palaung people in general and of the Ka-tur tribe in particular. The first half of the book is devoted to a sketch of the life-history of the people from childhood to marriage, and later chapters deal with special topics, which include law, medicine, religion, and mythology. Every aspect of the social life is considered. The authoress has contented herself with presenting the materials she has collected in a concise but interesting way, without attempting to trace their origins or relationships to other similar cultures. A much clearer picture of the life of the people is given in that way than by the method employed by many writers on descriptive anthropology, but it is to be hoped that Mrs. Milne will, in a later work, deal with her material from a comparative point of view.

Philologically the Palaungs are classed with the Mon-Khmer races ; they have no written script of their own. It is said that Buddhism did not settle in their hill country until the end of the eighteenth century, but it had probably affected the customs and beliefs of the people at a considerably earlier date. Buddhism is now the accepted religion, but it is associated with a very thorough-going form of spirit-worship. According to a legend of the Palaungs, the Buddha was once at a feast to which all the spirits were invited. Every one worshipped him except the rice-spirit. After meditating for a while, Gautama said, " I am really greater than the spirit of the paddy and all people should be grateful to me." And after sundry miraculous adventures the recalcitrant demon also saluted the Buddha, and the latter taught all people to pay obeisance to the paddy-spirit. It is in that fashion that the newly-come religion has imposed itself on the ancient spirit-worship. Hardly any of the old customs and beliefs can have been entirely eradicated. The majority have survived in a slightly changed form, and deprived of their original sinister meanings, so that many with an obviously barbarous origin are now harmless and even amiable. The Palaungs have " wise men " and witches, but their sayings are conventional and polite. The survivals of many of the practices which are associated with the most primitive stages of human culture are still clearly recognisable. Tatoomy is esteemed highly. There is a complicated initiation ceremony for young boys and girls in which animals made of bamboo and paper figure, and which ends with readings from the Buddhist scriptures. Marriage is preceded by elopement with the seemingly unwilling girl, and the father of the bridegroom must pay a certain sum of money to the father of the bride. And the scriptures are read again by the side of the coffin, in which food and tobacco and perhaps a flute or a comb lie with the dead body.

In providing a comprehensive account of an interesting social stage which will almost inevitably be transformed as Western ideas spread in the East, Mrs. Milne has rendered a valuable service to the cultural anthropologist, and her book will be of considerable interest to the general reader. There are numerous excellent photographs of the Palaungs themselves and of their houses and villages.

B.

Primitive Law. By E. Sidney Hartland, F.S.A. [Pp. vi + 222.] (London: Methuen & Co. Price 7s. 6d. net.)

Mr. Hartland has collected much primitive custom under the heading of *Primitive Law.* The origin of law is no doubt primitive custom, for the breach of which the sanctions may be as intense as, if not more intense than, the sanction of the civilised police-court. But the distinction between custom and law is perhaps worth making, whether we are disciples of Austen or not. There are many social customs in the various classes of civilised communities which have no legal sanctions behind them, but which members of those classes obey through growth of habit or because they actually fear sanctions, which are very real, if not legal in character, It would be inconvenient to call such customs "law"—we might then have to call professional etiquette law—and it would lead to the very confused thinking against which Austen rightly protested. However, Mr. Hartland does no great harm by terming his book *Primitive Law*; it at any rate emphasises the evolutionary source of law, and if the legal titles of his chapters be looked upon rather as suggesting the origin of later factors of positive law than as statements of fact, the student will be saved from confusion; we are dealing with the *evolution* of legal ideas, not with actual law.

Mr. Hartland tells us little that is new to the folklorist and anthropologist, but he groups his data by a new classification which is suggestive. A fault of the book is the absence of any full bibliography; the references to literature at the foot of the pages are so contracted that it is difficult for a student, who cannot be expected to be acquainted with the literature, to follow up the references. What can be made of "Univ. Cal. Pub.," or "Univ. Coll. Sub.," or "Internat. Arch.," by a student having at his command, say, only the *Catalogue of Periodical Publications of the British Museum*? No publication ought to cite a journal without its full title, place, and date of issue being readily discoverable in the publication itself. How many hours may be wasted over unstandardised contracted titles or authors' names (e.g. "Alldridge 161," or "Maclean 63"), without the statement of the book or year, only a critic like the present reviewer, who has to follow up many hundred references in a year, can fully appreciate! Perhaps, after all, the sin lies with Mr. Hartland's publisher rather than himself.

A source of material which Mr. Hartland never cites, but which is extraordinarily important if we are studying the evolution of custom into law, is provided by the various German and Austrian *Weisthümer*, which give, we venture to think, an intermediate link between the customs of primitive peoples (Mr. Hartland's Primitive Law) and the early written laws of the various Germanic and Slavonic peoples. Perhaps the somewhat anti-German feeling expressed in at least two passages of Mr. Hartland's book may account for his rather limited references to German sources. After all, those passages were not necessary and are somewhat out of place in the work of a scholar. Putting aside all these minor criticisms, the book is a useful book and can be commended as a preliminary study to the student of man. Like Dr. Haddon's *Races of Man*, it is, indeed, for the student and not for the teacher that such works are written, and for that purpose it is admirably fitted.

MISCELLANEOUS

Far Away up the Nile. By J. G. Millais. [Pp. x + 254, with 50 illustrations from drawings by J. G. Millais, H. R. Millais, and from photographs, and a map.] (London: Longmans, Green & Co., 1924. Price 30*s.* net.)

Far Away up the Nile is a worthy successor to the many other works dealing with natural history given to us by Mr. J. G. Millais. Its scientific value lies in the minute details and observations concerning the little-known big game of the Sudan. Some of these have been noted already by other competent field naturalists from time to time, but no other naturalist has yet been able to supplement his observations by such accurate drawings of the quaint habits and attitudes of the wild beasts which he has hunted. Some of these drawings bring back more vividly to the hunter the great charm of his hunting days and the familiar ways of many of the African fauna than pages of letterpress could ever do. Mr. Millais's son seems, judging by the numerous illustrations over his signature, to have inherited his father's gift of depicting wild beasts in their characteristic poses. The camera can never be expected to equal the pencil in this respect, and all naturalists will delight in this book because it takes them once again among the wild game and, so to speak, into their very haunts.

The vulture studies are particularly good, as also are the giant eland. Mrs. Gray's Kob, too, strike one as being excellent. A collection of studies of the quaint little dik-diks from Mr. Millais's or his son's pencil would have been very charming and instructive, as no artist has ever quite succeeded in just hitting off the very distinctive poses of these diminutive little creatures.

In this book Mr. Millais has given us a much better idea of the Sudan, its inhabitants, resources, together with its varied flora and fauna, than anyone else. His ethnological notes on the tribes he encountered, though short, are valuable. Not the least delightful part of this very interesting book on an imperfectly known part of our Empire is the charming dedication to those who toil " amid fearful heat and flies," and who not infrequently are only heard of when a short obituary notice in one of the daily papers announces their untimely end at the hands of those they are struggling to civilise or when some relentless tropical disease has slowly and surely claimed them at long last.

Mr. Millais, being a keen botanist, is able to give us not only the native but the correct botanical names of the trees and plants he describes, and this is a great help in distinguishing the regional flora.

The author speaks of the Dinkas as " taller than any other African natives, except perhaps the Zulus "; but is this correct ? The reviewer has always been under the impression that the Turkana, living on the shores of Lake Rudolf, have usually been considered by travellers to be the tallest of the African races. Although it is twenty-five years since the reviewer encountered the Turkana, the impression they left behind in his memory is that the average height of the male warriors must have been close on six feet.

The book is furnished with a useful map of the author's route, while it also gives the approximate distribution of the tribes in the Bahr el Ghazal. At the end is a valuable appendix describing some of the rarer antelopes.

Far Away up the Nile is a credit to author, publisher, and printer, and should certainly find a place in all libraries containing authoritative works on big game hunting. R. E. Drake-Brockman.

On the Edge of the Primeval Forest: Experiences and Observations of a Doctor in Equatorial Africa. By Prof. Albert Schweitzer. Translated by Ch. Th. Campion, M.A. [Pp. vi + 180, with 16 illustrations.] (London: A. & C. Black, 1924.)

The author informs us, to begin with, that he gave up his position of professor in the University of Strassbourg, his literary work, and his organ-playing, in

order to go as a doctor to Equatorial Africa. He did so under a humanitarian impulse as regards the natives. He graduated M.D. in 1913 and started with his wife, who had qualified as a nurse, for the River Ogowe in Equatorial Africa, the same year, because a doctor was badly needed there on account of the constantly spreading sleeping-sickness. The Alsatian Mission in the service of the Paris Evangelical Mission placed one of the houses in their station at Lambarene at his disposal and allowed him to build a hospital in their grounds. But he had to provide the actual expenses of the undertaking himself, and to that purpose he devoted what he had earned by giving organ-concerts together with the profits from his book on Bach, which had appeared in German, French, and English. Friends assisted him as regards these expenses. The country which he visited is mostly occupied with dense forest and water, and is admirably suited for the cultivation of coffee, pepper, cinnamon, vanilla, cocoa, and the oil palm—though the chief business of Europeans is the collection of rubber and the timber trade. Lambarene lies a little south of the equator and has a hot and moist climate which is very trying to Europeans. The book gives an admirable description of this country in a photographic style accompanied by good photographic plates, all of which will interest the reader. The author's comments on his experiences are characterised by philanthropy tempered with fairness and that species of sagacity which prefers truth to propaganda. He spent four and a half years as superintendent of the hospital which he constructed and concerns himself almost entirely with his own experiences and observations. The book does not contain matter of special interest to students of tropical medicine or zoology or botany. Nevertheless it gives us a good picture of life in that part of Africa, with a conscientious summary of many questions which occur in the locality dealt with.

Climatic Laws. By STEPHEN SARGENT VISHER, Ph.D. [Pp. 96, 9 figures.] (London: Chapman & Hall, 1924. Price 7*s*. 6*d*. net.)

IN this short work ninety " laws " are stated, with an explanatory paragraph to each. For illustration No. 72, selected at random, may be quoted. It is one of the " Laws Concerning Moisture " and states that: " Precipitation takes place more easily in winter than in summer, and at night than by day." Such a statement is hardly scientific, for the word " easy " is so vague that it is difficult to guess what is meant. One is told that " ease of precipitation does not, however, imply amount of precipitation " ; the expression is therefore robbed of what seems at first sight its most likely meaning ; the explanatory paragraph, moreover, does not indicate the criteria whereby one might estimate the relative " ease " with which the atmosphere contrived to produce a given quantity of rain on different occasions. On turning to the other laws one finds, frequently, a similar vagueness. For instance (law 43): " Exceptionally cold winds are often more powerful than relatively warm winds." With regard to the cold winds the author adds that " their density enables them to push harder than less dense winds " ; perhaps " powerful " here means " destructive " ; but surely blizzards are not as a rule more destructive than the winds in tornadoes and tropical cyclones ? Here, again, a word is evidently used in some special sense, without the necessary definition of its meaning. Considering the work as a whole, it seems doubtful whether it is desirable to try to formulate so many laws. One is tempted to think that a law achieves the maximum degree of usefulness only when it arises naturally in a discussion of climatic facts and their causes, such discussion being sufficiently thorough to indicate the limitations of the generalisation. This ideal is realised in a good treatise on climatology, but not in the present work.

E. V. NEWNHAM.

Spectroscopy. By E. C. C. BALY, F.R.S. Third Edition. Vol. I. [Pp. xi + 298, with 138 figures.] (London: Longmans, Green & Co., 1924. Price 14*s.* net.)

THE first edition of this book is dated 1905. The development of the subject since then has been of such an extensive and fundamental character that nothing less than rewriting could suffice to bring the work up-to-date. Prof. Baly deserves our gratitude for undertaking this heavy task, and our congratulations on the result before us. It is not surprising that he has found it necessary to expand the work considerably, and the volume under notice is the first of the two which will comprise the new edition. It deals with spectroscopic methods, with the exception of the Fabry-Perot and Lummer-Gehrcke interferometers, and represents rather more than one-half of the original volume. The size of the page has been increased, a distinct improvement, since it allows of a more convenient arrangement of the diagrams, Numerous additions and modifications have been made, and it is evident that the revision has been carried out with care and discrimination. The only obvious criticism is that the lengthy and detailed descriptions of the mounting of a concave grating and vacuum spectrograph are somewhat out of place in a work of this kind, so that some space might well have been saved by omitting them from this edition. We hope that Prof. Baly is making good progress with his second volume, for its appearance will be eagerly awaited by chemists and physicists alike. W. E. C.

Mathematical Analysis of Statistics. By C. H. FORSYTH, Assistant Professor of Mathematics, Dartmouth College (U.S.A.). [Pp. viii + 232, with Logarithm Tables.] (New York: John Wiley & Sons. London: Chapman & Hall, Ltd., 1924. Price 11*s.* 6*d.*)

A NUMBER of books on the mathematical theory of statistics have been published recently in America, and Prof. Forsyth's is one of the most satisfactory that we have come across. It does not attempt to go very far into the subject, but as the author states in the preface, it is offered as a textbook for a course in mathematics and not as a reference book for the statistician. It is a pity that courses on the elements of statistics are not given more often in this country. Quite recently at an English public school the boys in the senior mathematical division devoted an hour a week to the subject, and worked out for themselves standard deviations and correlation co-efficients. They enjoyed it thoroughly, and this is not surprising, as the subject with its ready application to problems of everyday life is both more interesting and more valuable than many of the branches of pure and applied mathematics that are commonly taught. The present book would form an excellent basis for such a school course.

The first essential for the statistician is that he should be familiar with his tools and able to handle them with accuracy; accordingly the first five chapters are devoted to "Errors and Numerical Computation"; "Finite Differences"; "Interpolation"; "The Gamma and Beta Functions"; "Probability."

After this the idea of Variation and the methods of its measurement and description are developed, and a good deal of attention is given to the Normal Curve and the Binomial. The final chapter deals with Correlation, not, however, going beyond linear regression and the product-moment method of calculating a correlation coefficient. A large number of exercises are given throughout, with problems taken from a wide range of subjects; many of these have been reproduced from published statistical papers sometimes with, but often without reference to the source. The notation employed is almost always that familiar to the English school of statisticians.

Various minor criticisms on the method of development of the subject might be made; for example, the relations between the normal curve and the binomial, and the conditions under which the latter can be represented adequately by the former, are nowhere clearly set out, while the student is hardly given enough warning of the danger of trusting to the probable error in dealing with small samples or in material following a skew distribution. But the task of the critic is easy, and it is only fair to say that the reader is clearly advised on the last page of the book to extend his study elsewhere on the subject of probable errors, of skew frequency-distributions, and of non-linear regression.

E. S. P.

Studies in Human Biology. By RAYMOND PEARL, Professor of Biometry at the Johns Hopkins University [Pp. 637.] (Baltimore: Williams & Wilkins Company, 1924.)

IN this book Prof. Pearl has put together, often in revised form, papers of his which have appeared during the past twenty years in various scientific journals. Many of them are unobtainable in separate form and their collection and republication is very welcome. The headings of the four parts into which the book is divided give a good idea of the wide scope of the work—" Considering Man as an Animal " ; " Biological Aspects of Vital Statistics " ; " Public Health and Epidemiology " ; " The Population Problem."

There are three chapters containing hitherto unpublished material: one on the Trends of Vital Indices concerned with the relative growth of the native and immigrant elements of population in the States, and its bearing on the question of Immigration Laws. A second discusses the Influence of Physical Activity upon Mortality; after a detailed analysis of the figures for Occupational Mortality published in 1923 by the Registrar-General for England and Wales, the writer comes to the conclusion that after the age of forty to forty-five, in nearly every walk of life, a man shortens his life by definite amounts in proportion as he performs physically heavy labour. Finally, in the concluding chapter, Prof. Pearl introduces the new type of theoretical curve representing population growth, which he discussed on several occasions during his visit to England last summer.

E. S. P.

North America: An Historical, Economic, and Regional Geography. By L. L. RODWELL JONES, B.Sc., and P. W. BRYAN, B.Sc. [Pp. xiii + 537, with 104 figures.] (London: Methuen & Co. Price 21s. net.)

THERE is an immense amount of material for the geography of North America already in existence ; but, as it occurs largely scattered through Government publications and in periodicals, the assembling and working up of it into a coherent and organic whole, as in this volume, is a valuable piece of work.

The book is divided into three sections: Historical, Economic, and Regional.

The Historical section shows the part played by Geography in shaping the course of North America's history, but does so with commendable caution. The attitude of the author (Mr. Rodwell Jones) is clearly shown in the following sentence : " In a work dealing with the influence of geographical environment, we must be careful not to overstate our case " (p. 62) ; and the same caution is shown in the mention of the *political* event which was the *immediate* cause of starting the Norsemen on the adventures which led them at length to " Vinland " (p. 11). Two of the maps specially prepared for this section are of particular interest, that of the settlements in Mexico at the end of the eighteenth century (p. 34), and that of the British Colonial Settlements (p. 71).

The Economic chapters, by Mr. Bryan, deal with the great commodities, such as cotton, wheat, coal, oil, and with the iron and steel industry. The chapters on this industry and on coal are particularly detailed, and the many original diagrams enhance their value; but there might be more acknowledgments in this section of the sources of the material used.

The last section, by Mr. Rodwell Jones, deals with the more important of the geographical regions, and is everywhere clear and well-reasoned; and, considering the small space (less than 200 pages) surprisingly "readable." The author deserves credit in particular for his insistence on synthetical diagrams, and—to instance a few only—that showing the relation between Relief and Town Population in New England (p. 332), that of Relief and Irrigation in California (p. 379), and that of Coastal Fogs and Redwoods in the same State (p. 385) are particularly illuminating.

The book tends in places to depart from the strictly geographical and to pass into the realm of pure economics, *e.g.* the details of the co-operative marketing of cotton (p. 188); but, in spite of small blemishes, it remains one of the most valuable additions to geographical literature which the last few years have produced.

M. R. SHACKLETON.

In Southern Seas: Wanderings of a Naturalist. By W. RAMSAY SMITH, M.D., D.Sc., F.R.S. [Pp. viii + 297, with 30 illustrations.] (London: John Murray. Price 16*s*. net.)

DR. RAMSAY SMITH is in this book professedly in holiday mood, and the book itself is a record of holidays spent in the Southern Seas, at Port Darwin in Northern Territory, and round the River Murray mouth in South Australia. The result is an entertaining volume, packed with shrewd observation and anecdotage, the whole strongly flavoured with the author's anthropological interests.

His journeyings took him from Sydney first among the brilliant colour, diversity of peoples, and often luxuriant vegetation of New Caledonia and the New Hebrides. The medley of peoples and customs in these French possessions evidently made a deep impression, not the least strange of the customs recorded being the survival of mummification in the Mallicolo Islands, where the head of the deceased is subjected to this process. There is an interesting chapter on civilisation and its meaning, and a comment on the difficulty of teaching about "the Lamb of God" where such mammals as sheep are unknown, after which the section on the South Seas is brought to a close with matter of anthropological interest, such as peculiarities of teeth, body scarring, causes of depopulation and so on.

In chapter x we meet the Australian "blackfella," and the remainder of the book is largely taken up with accounts of this interesting and little-understood people, either round Port Darwin, where they were present in considerable numbers, or among the River Murray lagoons—"where the pelican builds her nest"—where a few blackfellows killed snakes, did the cooking, and made themselves considerably more useful than white servants would have done in the same conditions. From the anthropological point of view this part of the book is perhaps the most interesting, and Dr. Ramsay Smith makes a fine defence of the aboriginal as a primitive, but by no means a degraded, race: "True, he has a longing every now and then to 'go bush,' to revert from civilised life to something like his normal conditions. But were Cincinnatus's reversions to his farm, or the longings of Horace or Virgil for country life, an evidence either of mental degeneracy or of moral relapse?" (p. 234).

A quotation from the Foreword by Prof. J. A. Thomson sums up the character of the book: "It is rich in anthropological insight and suggestion, very racy, yet very serious, very scientific, yet full of art."

M. SHACKLETON.

Physique and Character. E. Kretschmer. Translated from Second Edition by W. J. H. Sprott, B.A. The International Library of Psychology, Philosophy, and Scientific Method. 1925. [Pp. 266, 31 plates.] 10s.

The first German edition of this work was published in 1921, the second in 1922; the present volume is an English translation of the second edition. The work is based, in the first instance, on Kraepelin's differentiation of the insanities into the two main groups of manic-depressive madness and dementia præcox, and working backwards from this classification the author has attempted to establish two principal theses. The first of these is that the two groups mentioned above, which he designates respectively circular insanity and schizophrenia, pass over insensibly into two main types of temperament which he terms cyclothymic and schizothymic, of which they are derangements, and further that all individuals can be roughly sorted into these temperamental types. The second thesis is that these temperamental types are associated with distinctive types of physique, which are especially characterised by distinctive architecture of the head and face.

Since the argument has in reality developed in this manner from psychiatry to anthropometry, it is regrettable that the author has seen fit to reverse the order in his treatment of it in this volume, and has divided his subject into Part I: "Physique," and Part II, "The Temperaments." It is very evident that the author is a better psychiatrist than biometrician, and it is to be feared that many readers will fail to reach the end of Part I, as the reviewer would fain have done, and will thereby miss Part II, which has undoubted merit both in literary style and suggestiveness.

In his preface to the second edition the author says: "The only question is this: are there statistical relational-frequencies between certain forms of physique and certain psychical dispositions?" This is a good start, but we look in vain for any satisfactory answer to it in the 266 pages of this volume. In the first chapter is described a detailed scheme of classification of physical characters and measurements, and we are informed that the exposition which follows rests on material worked through by the aid of such a scheme and composed of eighty-five cases of circular insanity and 175 cases of schizophrenia divided into sexes. In the next chapter physique is classified into three types, "asthenic," "athletic," and "pyknic," and three tables of the "principal average measurements" of these types are given. By diligently searching the text one is able to discover that there were about 50 males and 20 females in the asthenic group, about 30 altogether in the athletic group, and no statement of the number in the pyknic group. Moreover, though we are given average physical measurements of the groups by sexes, we are told nothing about the ages of the cases, except that in table 4 male averages for ages 18–30 are separately compared; the numbers in these last groups must necessarily have been very small. Under these circumstances small differences in the average skeletal measurements carry very little conviction; the principal contrasts are in weight, chest, and abdominal girth, all possibly accountable for by fat deposition. The same is true of the average head dimensions; it remains doubtful whether any of the differences are significant, excepting perhaps in the horizontal circumference in males which is dependent on other factors besides the skull dimensions. The differences between the average measurements of the female heads are almost certainly not significant in amount, nor do these differences agree with those found in the male heads, even as regards their sign. When one further reads (p. 41) that "in many cases the structure of the face does not go parallel with the total structure of the body, so that we can find sometimes a head such as otherwise belongs to the pyknic type set on an asthenic body and vice versa," the doubts one has felt in studying these tables are further increased.

At first sight the rough sorting of circular and schizophrene cases amongst the physical types in Table 5 seems to indicate some correlation, but until the criteria which are alleged to distinguish the physical types have been proved to be anything more than variations in fatty and muscular development attributable to the influence of the endocrine glands or other factors, this does not seem to lead us far. One might similarly prove the association of quite a number of body measurements with exophthalmic goitre or phthisis, but one would have proved nothing thereby except that they were wasting diseases. The remaining chapters of this part of the book make dreary reading and present no evidence of a convincing kind.

In Part II, which is well written, the author seeks to divide humanity into two great temperamental types which are mild editions of the insanities; few people, we venture to think, will read this part without feeling some qualms as to whether they ought to be at large. The belief that certain types of insanity tend to be associated with certain temperaments, however, is not a new idea. In the last chapter it is suggested that the endocrine glandular system may have a profound if not all-important influence in the formation of temperament and character; such a possibility seems to be opposed by the accumulating evidence that an entire change in temperament and character may result from encephalitis lethargica, which is apparently purely a brain disease.

In justice to the author it must be admitted that he refrains from dogmatic assertion and advances his conclusions in a tentative manner as incentives to further research. This is all to the good; the principal fault which the reviewer has to find is that a thesis which can, as the author admits, only be proved or disproved statistically, has been advanced in this book with a certain amount of statistical material behind it, in such a manner as to leave a biometrician entirely in doubt as to whether the material proves anything or not. The vague and inadequate treatment of the figures which are in the author's possession is not due to lack of space in a book of this size—would it not have been more profitable to produce the evidence first and discuss it at length afterwards rather than to adopt the reverse procedure? Until this is done the book suggests much but proves little or nothing.

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BOOKS RECEIVED

(Publishers are requested to notify prices)

The Theory of Quantitative Analysis and its Practical Application. By Henry Bassett, D.Sc., Ph.D. London: George Routledge & Sons, 68 Carter Lane, E.C., 1925. (Pp. viii + 308.) Price 15*s.* net.

Conformal Representation. By Leo Lewent. Translated by R. Jones, M.A., D.Sc., and D. H. Williams, B.Sc. London: Methuen & Co., 36 Essex Street, W.C. (Pp. viii + 146, with 40 diagrams.) Price 7*s.* 6*d.* net.

Hints on Notemaking in Science and Mathematics. For Students and Teachers. By R. T. Hughes, M.A., Assistant Master at Harrow School. London: G. Bell & Son, 1925. (Pp. vi + 132.) Price 2*s.* 6*d.* net.

An Enquiry Concerning the Principles of Natural Knowledge. By A. N. Whitehead, Sc.D., F.R.S., Fellow of Trinity College, Cambridge. Cambridge: at the University Press, 1925. (Pp. xiv + 207.) Price 12*s.* 6*d.* net.

Elements of the Mathematical Theory of Limits. By J. G. Leathem, Sc.D., M.R.I.A., Fellow and Senior Bursar of St. John's College, Cambridge. London: G. Bell & Sons, 1925. (Pp. viii + 288.) Price 14*s.* net.

Cours de Mathématiques Générales à l'usage des Étudiants en Sciences Naturelles. Par Gustave Verriest, Professeur à l'Université de Louvain. Seconde Partie. Géométrie Analitique à Trois Dimensions Calcul Intégral. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins; Louvain: Éditions Universitas, 87 Rue de Manur. (Pp. 388.) Price 38 frs.

History of Mathematics. Vol. II. Special Topics of Elementary Mathematics. By David Eugene Smith. London: Ginn & Company (Pp. xii + 725.) Price 21*s.* net.

La Comptabilité Moderne Essai de Constitution Rationnelle Rationnelle d'une Discipline Comptable au Triple Point de Vue Philosophique, Scientique, et Technique. Par J. Dumarchey. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1925. (Pp. 372.) Price 40 frs.

Notations et Formules Vectorielles. Par A. Lafay, Professeur de Physique à l'École Polytechnique, Paris. Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1925. (Pp. 36.) Price 6 frs.

The Elements of Mechanics. By F. S. Carey, M.A., Professor Emeritus in the University of Liverpool, and J. Proudman, M.A., D.Sc., Professor in the University of Liverpool. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. ix + 314.) Price 8*s.* 6*d.* net.

The Common Sense of the Theory of Relativity. By Paul R. Heyl, Ph.D., Physicist Bureau of Standards. Washington, D.C. Baltimore: Williams & Wilkins; London: Baillière, Tindall & Cox, 1924. (Pp. 44.) Price 5*s.* net.

La Relativité Dégagée d'Hypothèses Métaphysiques. Par H. Varcollier, Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins. (Pp. 542.) Price 50 frs.

Physico-Chemical Evolution. By Ch. Eug. Guye, Professor of Physics at the University of Geneva. Translated by J. R. Clarke, M.Sc., F.Inst.P. London: Methuen & Co., 36 Essex Street, W.C. (Pp. xii + 172, with 4 diagrams.) Price 6*s.* net.

A German-English Dictionary for Chemists. By Austin M. Patterson, Ph.D., New York: John Wiley & Sons; London: Chapman & Hall, 1924. (Pp. xvi + 316.) Price 12*s.* 6*d.* net.

Les Notions Fondamentales d'Élément Chimique et d'Atome. Par Georges Urgain. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins. (Pp. 172.) Price 10 frs. net.

New Reduction Methods in Volumetric Analysis. A Monograph. By Edmund Knecht, Ph.D., M.Sc., Tech.F.I.C., Associate Professor of Applied Chemistry in the Victoria University of Manchester, and in the Municipal College of Technology, Manchester, and Eva Hibbert, M.Sc., Tech. Assistant Lecturer in the Victoria University of Manchester, and in the Municipal College of Technology, Manchester. Second Edition. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. x + 134.) Price 8*s.* 6*d.* net.

The Foundations of Colloid Chemistry. A Selection of Early Papers Bearing on the Subject. Edited, on behalf of the Colloids Committee of the British Association, by Emil Hatschek, F.Inst.P., Lecturer on Colloid at the Sir John Cass Technical Institute, London. London: Ernest Benn, 8 Bouverie Street, E.C.4, 1925. (Pp. 173.) Price 18*s.* net.

A Class-Book of Chemistry. By G. C. Donington, M.A. Part V, Organic Chemistry. By T. M. Lowry, C.B.E., D.Sc., F.R.S., and P. C. Austin, M.A., D.Sc., F.I.C. London: Macmillan & Company, St. Martin's Street, 1925. (Pp. 531–766.) Price 3*s.* net.

A Student's Manual of Organic Chemical Analysis. Qualitative and Quantitative. By Jocelyn Field Thorpe, C.B.E., D.Sc., Ph.D., F.R.S., F.I.C., and Martha Annie Whiteley, O.B.E., D.Sc., A.R.C.S., F.I.C. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. x + 250, with 33 figures.) Price 9*s.* net.

Chemistry to the Time of Dalton. By E. J. Holmyard. London: Oxford University Press, 1925. (Pp. 128.) Price 2*s.* 6*d.* net.

Introduction to Qualitative Organic Analysis. By Hermann Staudinger, Ph.D. Authorised Translation by Walter T. K. Braunholtz, M.A., Ph.D., F.I.C. London: Gurney & Jackson; Edinburgh: Olive & Boyd, Tweeddale Court, 1925. (Pp. xvi + 112.) Price 6*s.* 6*d.* net.

The Principles of Thermodynamics. By George Birtwhistle, Fellow of Pembroke College, Cambridge. Cambridge: at the University Press, 1925. (Pp. ix + 163.) Price 7*s.* 6*d.* net.

British Chemicals, Their Manufacturers and Uses. Being the Official Directory of the Association of British Chemical Manufacturers, containing a Full List of Members with a Classified List of British Chemicals, and a Note of their Industrial Applications. London: Ernest Benn, 166 Piccadilly, W.1. (Pp. 212.) Price 10*s.* 6*d.* net.

Physical Chemistry: Its Bearing on Biology and Medicine. By James C. Philip, O.B.E., D.Sc., F.R.S., Professor of Physical Chemistry, Imperial College of Science and Technology, London. Third edition. London: Edward Arnold & Co., 1925. (Pp. vii + 367.) Price 8*s.* 6*d.* net.

Premier Conseil de Chimie Tenu à Bruxelles du 21 au 17 Avril 1922 sous les Auspices de l'Institut International de Chimie Solvay. Rapports et Discussions Publiés par la Commission Administrative de l'Institut et MM. les Secrétaires du Conseil sur Cinq Questions d'Actualité. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins. (Pp. 336.) Price 30 frs.

✓ Modern Inorganic Chemistry. By J. W. Mellor, D.Sc. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. xx + 1103.) Price 12*s.* 6*d.* net.

Useful Aspects of Geology. By S. J. Shand, D.Sc., Ph.D., F.G.S., Professor of Geology and Mineralogy in the University of Stellenbosch, South Africa. London: Thoman Murby & Sons, 1 Fleet Lane, E.C.4, 1925. (Pp. x + 197, with 23 figures.) Price 7*s.* 6*d.* net.

Handbook of the Geology of Ireland. By Grenville A. J. Cole, D.Sc., F.R.S., M.R.I.A., and T. Hallissy, B.A., M.R.I.A., with Preface by John W. Evans, C.B.E., D.Sc., F.R.S., President of the Geological Society. London: Thomas Murby & Co., 1 Fleet Lane, E.C.4, 1924. (Pp. viii + 82, with 7 figures.) Price 8*s.* 6*d.* net.

Plant Life on East Anglian Heaths. Being Observational and Experimental Studies of the Vegetation of Breckland. By E. Pickworth Farrow, M.A., D.Sc. Cambridge: at the University Press, 1925. (Pp. x + 108, with 46 illustrations.) Price 7*s.* 6*d.* net.

The Botany of Crop Plants: A Text and Reference Book. By Wilfred W. Robbins, Associate Professor of Botany, College of Agriculture, University of California. Second Edition. Philadelphia: P. Blakiston Son & Co., 1012 Walnut Street. (Pp. xxi + 674, with 263 illustrations.) Price $3.50.

The Romance of the Fungus World: An Account of Fungus Life in its numerous guises, both real and legendary. By R. T. Rolfe, F.I.C., Member of the British Mycological Society, and F. W. Rolfe, Member of the British Mycological Society. With Foreword by J. Ramsbottom, O.B.E., M.A., F.L.S. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1925. (Pp. xx + 309, with 85 figures.)

Plants and Man. A Series of Essays relating to the Botany of Ordinary Life. By F. O. Bower, Sc.D., LL.D., F.R.S. Emeritus Professor of Botany, University of Glasgow. London: Macmillan & Co., St. Martin's Street, 1925. (Pp. xii + 365, with 148 figures.) Price 14*s.* net.

Œcology of Plants. An Introduction to the Study of Plant-Communities. By Eug. Warming, Ph.D., Professor of Botany in the University of Copenhagen. Assisted by Martin Vahl, Ph.D., Privatdocent in the University of Copenhagen. Prepared for Publication in English by Percy Groom, M.A., D.Sc., F.L.S., Assistant Professor of Botany in the Imperial College of Science and Technology, London, and Isaac Bayley Balfour, M.A., M.D., F.R.S., King's Botanist in Scotland, Regius of Botany in the University, Edinburgh. London: Oxford University Press. (Pp. xi + 422.) Price 15*s.* net.

Imperial Botanical Conference. London: July 7–16. 1924. President, Sir David Prain, C.M.G., C.I.E., F.R.S. Held at the Imperial College of Science and Technology, South Kensington, by kind permission of the Governing Body. Report of Proceedings edited by F. T. Brooks, Hon. Secretary. Cambridge: at the University Press, 1925. (Pp. xv + 390.) Price 15*s.* net.

Genetics in Plant and Animal Improvement. By Donald Forsha Jones, Connecticut Agricultural Experiment Station, New Haven. New York: John Wiley & Sons; London: Chapman & Hall, 1925. (Pp. viii + 568, with 229 figures.) Price 20*s.* net.

Animal Breeding. By Laurence M. Winters, M.S. Professor of Animal Husbandry, University of Saskatchewan. New York: John Wiley & Sons. London: Chapman & Hall. (Pp. x + 309.) Price 13*s.* 6*d.* net.

The American Museum of Natural History. Fifty-fifth Annual Report of the Trustees for the year 1923. The City of New York. Issued July 15, 1924. (Pp. xxiv + 267.)

The Dogma of Evolution. By Louis Trenchard More, Professor of Physics, University of Cincinnati. Lectures delivered at Princeton University, January 1925. Princeton: Princeton University Press, 1925. (Pp, iv + 287.) Price 16*s.* net.

Outlines of General Zoology. By Horatio Hackett Newmann, Professor of Zoology in the University of Chicago. New York: The Macmillan Company, 1924. (Pp. xvi + 480, with 179 figures.) Price 16*s.* net.

A General Textbook of Entomology. Including the Anatomy, Physiology, Development and Classification of Insects. By A. D. Imms, M.A., D.Sc., Chief Entomologist, Rothamsted Experimental Station, Harpenden. London: Methuen & Co., 36 Essex Street, W.C. (Pp. xii + 698, with 604 illustrations.) Price 36*s.* net.

The Cell in Development and Heredity. By Edmund B. Wilson, Da Costa Professor of Zoology, Columbia University. Third Edition, revised and enlarged. New York: The Macmillan Company, 1925. (Pp. xxxvii + 1232, with 529 figures.) Price 36*s.* net.

The Early Embryology of the Chick. By Bradley M. Patten, Associate Professor of Histology and Embryology, School of Medicine, Western Reserve University. Second Edition. Philadelphia: P. Blakiston's Son & Co., 1012 Walnut Street. (Pp. xi + 177, with 213 figures.)

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SCIENCE PROGRESS

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PURE MATHEMATICS. By F. Puryer White, M.A., St. John's College, Cambridge.

Hypergeometric Functions of Several Variables.—The hypergeometric series

$$F(\alpha, \beta, \gamma, x) \equiv 1 + \frac{\alpha \, . \, \beta}{\gamma \, . \, 1} x + \frac{\alpha(\alpha+1) \, . \, \beta(\beta+1)}{\gamma(\gamma+1) \, . \, 1 \, . \, 2} x^2 + \ldots$$
$$\equiv \sum_m \frac{(\alpha, m)\,(\beta, m)}{(\gamma, m)\,(1, m)} x^m,$$

where (λ, k) is written for $\Gamma(\lambda + k)/\Gamma(\lambda)$, can be generalised to a series in two variables in the following way. The general term in the series obtained by multiplying two ordinary hypergeometric series $F(\alpha, \beta, \gamma, x)$ and $F(\alpha', \beta', \gamma', y)$ is

$$\frac{(\alpha, m)\,(\alpha', n)\,(\beta, m)\,(\beta', n)}{(\gamma, m)\,(\gamma', n)\,(1, m)\,(1, n)} x^m y^n.$$

We modify this by replacing one, two, or three of the products

$$(\alpha, m)\,(\alpha', n),\ (\beta, m)\,(\beta', n),\ (\gamma, m)\,(\gamma', n)$$

by

$$(\alpha, m+n),\ (\beta, m+n),\ (\gamma, m+n).$$

Of the five possible combinations one arises simply from the development of the function $F(\alpha, \beta, \gamma, x+y)$; the other four give four new double series which are denoted as follows:

$$F_1(\alpha, \beta, \beta', \gamma, x, y) \equiv \sum \frac{(\alpha, m+n)\,(\beta, m)\,(\beta', n)}{(\gamma, m+n)\,(1, m)\,(1, n)} x^m y^n,$$
$$F_2(\alpha, \beta, \beta', \gamma, \gamma', x, y) \equiv \sum \frac{(\alpha, m+n)\,(\beta, m)\,(\beta', n)}{(\gamma, m)\,(\gamma', n)\,(1, m)\,(1, n)} x^m y^n,$$
$$F_3(\alpha, \alpha', \beta, \beta', \gamma, x, y) \equiv \sum \frac{(\alpha, m)\,(\alpha', n)\,(\beta, m)\,(\beta', n)}{(\gamma, m+n)\,(1, m)\,(1, n)} x^m y^n,$$
$$F_4(\alpha, \beta, \gamma, \gamma', x, y) \equiv \sum \frac{(\alpha, m+n)\,(\beta, m+n)}{(\gamma, m)\,(\gamma', n)\,(1, m)\,(1, n)} x^m y^n.$$

The single-valued functions defined by these four series and their analytic continuations in suitably slit x and y planes are called hypergeometric functions of two variables ; they were first introduced in 1880 by P. Appell, who has recently published a pamphlet (*Mémorial des Sciences Mathématiques*, fasc. 3, Paris, 1925) in which the properties of these functions are summarised—he also announces a larger work on the subject, in which he is collaborating with J. Kampé de Fériet. A good many of the known properties of the ordinary hypergeometric functions are capable of immediate generalisation to the new functions ; for example, they can be represented as double integrals or as contour integrals. Also, each of the four functions satisfies a system of linear partial differential equations of the second order. The functions F_2, F_3, F_4 each satisfy two equations of the type

$$r = a_1(x, y)\, s + a_2(x, y)\, p + a_3(x, y)\, q + a_4(x, y)\, z,$$
$$t = b_1(x, y)\, s + b_2(x, y)\, p + b_3(x, y)\, q + b_4(x, y)\, z,$$

and we can form for each a fundamental system of four integrals, such that the general integral is a linear combination of these four. For example, for the equations of F we have the general integral

$$z = A\, F_2(\alpha, \beta, \beta', \gamma, \gamma', x, y) + B\, x^{1-\gamma} F_2(\alpha + 1 - \gamma, \beta + 1 - \gamma, \beta', 2 - \gamma, \gamma', x, y) + C y^{1-\gamma'} F_2(\alpha + 1 - \gamma', \beta, \beta' + 1 - \gamma', y, 2 - \gamma', x, y) + D x^{1-\gamma} y^{1-\gamma'} F_2(\alpha + 2 - \gamma - \gamma', \beta + 1 - \gamma, \beta' + 1 - \gamma', 2 - \gamma, 2 - \gamma', x, y).$$

Naturally we must suppose that γ, γ' are not integers, in the same way that for γ integral we have a logarithmic term in the general integral of the ordinary hypergeometric equation.

The function F_1 satisfies three simultaneous linear equations, one of which is a consequence of the other two, and we have the result that just as the hypergeometric equation has 24 integrals of the form $x^l (1 - x)^m F(\lambda, \mu, \nu, t)$, where t is rational and of the first degree in x, so we can find 60 functions of the type $x^l (1 - x)^m y^{l'} (1 - y)^{m'} (x - y)^n F_1(\lambda, \mu, \mu', \nu, t, t')$, t and t' being rational in x and y, which satisfy the system of partial differential equations of F_1.

As far back as 1857 Riemann defined the hypergeometric equation as a function of the complex variable by the three singular points of its differential equation and the exponents at these points. In a similar way, using the methods of Pochhammer, Goursat has shown that the functions F_2, F_3, F_4 can be defined by their critical points and the corresponding exponents. For the function F_1, satisfying three linear partial differential equations, the investigation has been carried through by Picard ; he has also examined how the general integral of the equations is transformed when the variables x and y describe closed paths round one of the singular points—*i.e.* he has determined the group of the equations of F_1. A connected problem is the inversion of the quotient of two integrals : under what conditions are the functions $x(s, t)$ and $y(s, t)$ defined by the relations

$$s = \frac{\omega_1(x, y)}{\omega_3(x, y)}, \qquad t = \frac{\omega_2(x, y)}{\omega_3(x, y)},$$

$\omega_1, \omega_2, \omega_3$ being particular integrals of the equations, single-valued functions of s and t? The similar problem for the ordinary hypergeometric equations led Poincaré to a particular class of fuchsian functions. In our case it is necessary that ten numbers should be reciprocals of integers, and there are 102 systems of numbers satisfying these conditions ; the functions x and y are included in the class of hyperfuchsian functions. In particular, for the case corresponding to $F_1(\frac{1}{3}, \frac{1}{3}, \frac{1}{3}, 1, x, y)$, where the integrals ω are of the form

$$\int_g^h [u(u-1)(u-x)(u-y)]^{-\frac{1}{3}}\, du,$$

the single-valued functions $x(s, t)$ and $y(s, t)$ play in the theory of the abelian functions arising from the algebraic equation

$$v^3 = u(u-1)(u-x)(u-y)$$

the same part that the modular function plays in the theory of the elliptic functions.

The two linear partial differential equations arising for any one of the functions F_2, F_3, F_4 have, as we have remarked, four linearly independent common integrals. If we establish a relation between x and y, $y=f(x)$, the general integral of the equations will become a function of x only, and this function z will satisfy, in general, a linear equation of the fourth order. It may happen that for certain special functions $f(x)$ the function z satisfies a differential equation of order less than 4. The order is, in fact, three if $y = f(x)$ is a solution of a non-linear differential equation of order 3, the *reducing equation*, which is connected in an invariant manner with the original pair of equations. The general integral of the reducing equation is

$$K_1 z_1 + K_2 z_2 + K_3 z_3 + K_4 z_4 = 0,$$

where z_1, z_2, z_3, z_4 are a fundamental system of integrals of the original equations; and, conversely, if we know the general integral of the reducing equation, we can obtain the general integral of the original equations by the integration of a total differential in two variables. Work on these lines has been done by P. Appell (*Rend. Palermo*, 47, 1923, 15–16).

Another type of reduction which has also been studied by Appell (*C.R.*, **167**, 1918, 408–13) arises when for certain relations between the elements α, β, α^1, β^1, γ, γ^1 the function satisfies, not only the original system of partial differential equations, but also an analogous system, with coefficients rational in x and y, the general integral of which contains less than four arbitrary constants.

If we take a linear differential equation with three regular singularities and make two of the singularities coalesce, we obtain an equation with one regular and one irregular singularity. In this manner we obtain what is known as the confluent hypergeometric function, by means of which the Bessel function and various other functions which turn up in applied mathematics can be expressed (see Whittaker and Watson, *Modern Analysis*, chap. xvi). In a similar way P. Humbert (*Proc. Roy. Soc. Edin.*, **41**, 1921, 73–96 ; *C.R.*, **171**, 1920, 428–30) has obtained confluent hypergeometric functions of two or more variables.

For one variable the hypergeometric function can be extended in two ways, and both of these can be applied to our functions of two variables. The first is the method of Pochhammer, and in our case would lead to the investigation of integrals of the form

$$s(x, y) = \int_g^h (u-a_1)^{b_1-1} \ . \ . \ . \ (u-a_k)^{b_k-1} (u-x)^{\lambda-1} (u-y)^{\mu-1}\, du,$$

where g and h denote two of the quantities a_1, . . . a_h, ∞, x, y. This has not yet been carried out in a systematic way, but M. Appell points out that the systems of linear partial differential equations which arise have been dealt with to some extent by R. Garnier in his *Thèse* on differential equations with fixed critical points. The second method, which has been the subject of memoirs by H. Mellin (*C.R.* **172**, 1921, 658–61), R. Birkeland (*C.R.*, **171**, 1920, 1370–2 ; *ibid.*, **172**, 1921, 309–11, 1155–8), and J. Kampé de Fériet (*ibid.*, **172**, 1921, 1634–6 ; **173**, 1921, 285–8, 401–4, 489–91), considers as the most general hypergeometric function of two variables any function defined by a double series $\Sigma a_{m,n} x^m y^n$, of which the coefficients satisfy the relations

$$\frac{a_{m+1,n}}{a_{m,n}} = \frac{\mathrm{P}(m, n)}{\mathrm{R}(m, n)} \qquad \frac{a_{m,n+1}}{a_{m,n}} = \frac{\mathrm{Q}(m, n)}{\mathrm{S}(m, n)};$$

P, Q, R, S being polynomials, R and S not vanishing for any values of the positive integers m, n, the degrees of P and Q being at most equal to those of R and S, and the two relations being compatible. For one variable the polynomials P (n) and R (n)

can always be split up into linear factors, and we get only series of the type

$$\mathrm{F}(x) = \Sigma \frac{(\alpha_1, n) \ . \ . \ . \ (\alpha_\mu, n)}{(\beta_1, n) \ . \ . \ . \ (\beta_\nu, n)\,(1, n)}\, x^n,$$

for two variables this decomposition is not generally possible; the exceptional case in which it is possible has been discussed in detail by Kampé de Fériet, who calls the functions hypergeometric functions of higher order.

Another definition which is capable of generalisation is that of the Bessel coefficients as coefficients of t^n in the expansion of the function exp. $\{\frac{1}{2}z\,(t - 1/t)\}$; this has been done by Pérès (*C.R.*, **161**, 1915, 168–70), Jekowsky (*ibid.*, **162**, 1916, 318–19; **164**, 1917, 719–21; *Bull. sci. math.*, **41**, 1917, 58) and Akimof (*C.R.*, **163**, 1916, 26–9; **165**, 1917, 23–5, 1100–3; **179**, 1924, 435–7).

Just as the Legendre polynomials arise as a particular case of the hypergeometric function, so we may obtain polynomials in two variables from the function F_2. They were first considered by Hermite, who defined them by the expansion

$$\{(1 - ax - by)^2 + (a^2 + b^2)\ (1 - x^2 - y^2)\}^{-\frac{1}{2}} = \Sigma a^m b^n \mathrm{U}_{m,n}$$

analogous to the expansion

$$(1 - 2ax + a^2)^{-\frac{1}{2}} = \{(1 - ax)^2 + a^2\ (1 - x^2)\}^{-\frac{1}{2}} = \Sigma a^n \mathrm{P}_n.$$

The analogy becomes more striking when we find that

$$\mathrm{U}_{m,n} = \frac{1}{2^{m+n}\, m\,!\, n\,!}\ \frac{\partial^{m+n}\,(x^2 + y^2 - 1)^{m+n}}{\partial x^m\, \partial y^n}$$

just as
$$\mathrm{P}_n = \frac{1}{2^n n\,!}\ \frac{d^n\,(x^2 - 1)^n}{dx^n}$$

and that the new polynomials satisfy two partial differential equations of the second order which may be compared with Legendre's equation. Moreover, the polynomials are orthogonal in the sense that the double integral

$$\iint \mathrm{U}_{m,n} \mathrm{U}_{\mu,\nu}\, dx\, dy,$$

taken over the circle $x^2 + y^2 - 1 \leq \mathrm{O}$, is zero as long as $m + n$ is not equal to $\mu + \nu$. To calculate the coefficients in the development of a function as a series in $\mathrm{U}_{m,n}$, Hermite associates with these polynomials other polynomials $\mathrm{V}_{m,n}$ defined by the expansion

$$(1 - 2ax - 2by + a^2 + b^2)^{-1} = \Sigma a^m b^n \mathrm{V}_{m,n},$$

showing that $\iint \mathrm{U}_{m,n} \mathrm{V}_{\mu,\nu}\, dx\, dy$ taken over the unit circle is zero unless $\mu = m$ and $\nu = n$, when it takes the value

$$\frac{\pi}{m + n + 1}\ \frac{(m + n)\,!}{m\,!\, n\,!}$$

It further appears that the polynomials $V_{m,n}$ may be regarded as spherical harmonics in four dimensions. The function $T = (x_1^2 + x_2^2 + \ldots + x_q^2)^{1-\frac{1}{2}q}$ satisfies the equation

$$\Delta T \equiv \frac{\partial^2 T}{\partial x_1^2} + \frac{\partial^2 T}{\partial x_2^2} + \ldots + \frac{\partial^2 T}{\partial x_q^2} = 0$$

(with a logarithm for $q = 2$). Thus for $q = 4$ we have the "potential" $T = (x^2 + y^2 + z^2 + t^2)^{-1}$. Differentiating T partially m times with regard to x and n times with regard to y, we obtain a function W which is still a solution of $\Delta W = 0$, and which can be expressed as the quotient of a polynomial in x, y, and r by an integral power of r, where r stands for $(x^2 + y^2 + z^2 + t^2)^{\frac{1}{2}}$. For $r = 1$ this polynomial, save for a numerical factor, becomes $V_{m,n}$.

Uniform Functions with an Isolated Essential Singularity.—It was shown by Weierstrass (1876) that in the neighbourhood of an isolated singularity a uniform function approaches as near as we please to any arbitrarily assigned value. In 1879 Picard added an important result which has been the starting-point of a whole series of researches; in the neighbourhood of the essential singularity the function actually assumes an infinity of times every value save two possible exceptional values. This, or the form it takes for integral functions—given an integral function $f(x)$, there is at most one finite number a such that the equation

$$f(x) - a = 0$$

has no roots—is known as Picard's theorem, and was proved by him by means of the elliptic modular function. Attempts were made to give a proof of a more "elementary" kind, without appeal to the properties of a special transcendental function, and Hadamard (1892) and Borel (1895) were successful. Their work depends on the investigation of the function $M(r)$, the maximum for $z = r$ of the modulus of the function. It was shown by Hadamard that $\log M(r)$ is a continuous, convex, and ultimately increasing function. Borel introduced the notion of order of a function, the upper limit as r tends to infinity of the ratio $\log \log M(r) : \log r$—if this is finite the relations between $M(r)$ and the maximum term, *i.e.* the function which for each r is equal to the greatest of the numbers $|c_n| r^n$, the moduli of the terms in the expansion of the function, assume a simple form, and, in fact, functions of finite order were for a long time the only ones for which simple and precise results were obtained. A still narrower class is the class of functions *of regular growth*, for which the ratio $\log \log M(r) : \log r$ tends to a finite number as r tends to infinity. The results of Borel have been made more precise by Wiman (*Acta Math.*, 37, 1914, 305–26; 41, 1918, 1–28) and still more recently by G. Valiron (*Ann. École Norm.*, **39**, 1922, 317, or see his book *Lectures on Integral Functions*, 1923, chap. 4); the latter investigates the behaviour of the function $f(z)$ in the neighbourhood of points z_0 at which $|f(z_0)| = M(r)$, deduces a direct proof of Picard's theorem and extends Borel's theorems to functions of infinite order.

We have stated that the original proof of Picard's theorem made use of the elliptic modular function, and it is by this means that extensions have been made by Landau, Schottky, and Carathéodory. Indeed, it has been shown by the last-named author that the modular function is essential to the complete theory, thus confirming the statement made in 1889 by Picard: "Il est dans la nature des choses, semble-t-il, de s'adresser à une fonction possédant précisément la propriété qu'on veut démontrer ne pouvoir appartenir aux fonctions entières." The most complete account of the theory from this point of view is contained in a recent volume of the Borel tracts by G. Julia: *Les fonctions uniformes à point singulier essentiel* (1923); a summary is also given by G. Valiron (*Mémorial des Sci. Math.*, fasc. 2, 1925). In this connection the *normal families* of functions, introduced by Montel, are of importance; from every sequence of functions belonging to such a family we can select another sequence which converges uniformly to a limiting function, which may be constant or infinite. It is proved that any set of functions regular in a circle within which they cannot assume either of the values 0 or 1 constitutes such a normal family, and thence are obtained properties of functions which are regular in a sector in which they do not assume the values 0 and 1. Other results, due to Julia, are obtained by considering the properties of the special family $F(z\sigma^n)$, in which $|\sigma| < 1$.

ASTRONOMY. By W. M. H. Greaves, M.A., Royal Observatory, Greenwich.

Systematic Errors in Star-places and Proper Motions.—The many and important recent researches in astrophysics must have tended to obscure in the minds of many the necessity of steady and continuous work in that domain of astronomy to which the term "fundamental astronomy" is usually applied. But, nevertheless, the continuous observation of the positions of stars in the sky and the comparison of observations at widely separated epochs leading to the determination of proper motions must necessarily form the basis on which a large proportion of our knowledge of the sidereal universe must be built. It is highly important that observed star-places should be free from serious systematic error, and the present article will be devoted to an account of recent discussions of systematic errors in catalogues of stars observed with transit circles.

It is chiefly in the observed declinations that such errors are apt to be troublesome. It will be remembered that, some fourteen years ago Lewis Bors, determined the solar apex (that is, the point in the sky towards which the solar system is moving relatively to the stars) from the proper motions of the 6,188 stars in his *Preliminary General Catalogue*. The solar apex can also be determined from a discussion of line-of-sight velocities, and it is a matter of history that the positions of the apex, obtained in these two ways, differ by some ten degrees in declination, a difference which is far more than can be attributed to accidental error.[1] It is at once suggested that either the proper motions or the radial velocities are affected by systematic error, and Kapteyn has pointed out that the discrepancy would be removed if the proper motions in Bors's catalogue were to be increased by a correction proportional to the course of the declination.

W. S. Eichelberger, in the preface to vol. x, part 1, of the "Astronomical Papers" of *The American Ephemeris*, discusses the systematic errors in four star catalogues, viz. the First and Second Cape Fundamental Catalogues for the Equinox, 1900, and two recent Washington catalogues comprising observations made with the 9-inch and 6-inch transit circles.

The chief known causes of systematic error in determinations of declination with transit circles are flexure of the instrument and errors in the assumed refractions. The first of these would lead to an error depending on the rim of the zenith distance, and the second would lead to an error depending on the tangent of the zenith distance. There may possibly also be other sources of error of unknown origin. In any case, the observations are right at the pole, the declinations of close polar stars consisting of measures between the positions of each star at upper and lower culmination, which measures converge to zero at the pole itself. The errors in declination at the equator can be obtained from observations of the sun and inner planets, and, this having been done, it remains to determine how the correction varies as we pass from the pole to the equator.

The Cape observations of the Sun, Mercury, and Venus indicate a correction of $0''\cdot25$ in the neighbourhood of the equator to the First Cape Catalogue and a correction of $0''\cdot47$ to the Second Catalogue. As regards the Washington 9-inch observations a correction of $-0''\cdot48$ was obtained. The results for the 6-inch observations were not available.

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[1] See Eddington, *Stellar Movements*, chapter v.

Eichelberger tabulates the differences between the declinations of the two Washington catalogues and also the differences between the declinations of the two Cape catalogues. Several attempts were made to represent these differences by algebraic expressions. The best fit was obtained with an expression of the form $x + y \sin z$, and the next best fit with an expression of the form $m + n \cos \delta$, where z denotes zenith distance and δ declination. He then assumes that the systematic correction to be applied to the declinations of any catalogue must be of one of these two forms, and he analyses the two Cape Catalogues and the Washington 9-inch catalogue for each algebraical form, the constants being determined so as to make the corrections have the observed values at the equator and vanish at the pole. Before analysing the Cape observations a correction was applied to the refractions with which the observations were originally reduced so as to make them conform more closely with the Washington observations.[1]

The differences between the Washington 6-inch and the corrected results from the Second Cape Catalogue were then formed and analysed in the two forms. The resulting expressions should represent the corrections to the 6-inch catalogue. It was found that if the form $x + y \sin z$ be adopted for the Cape observations the Washington 6-inch observations would be wrong at the pole by a second of arc irrespective of the form in which the differences Washington *minus* Cape were analysed. Such an error would be quite inadmissible. If, however, Cape observations were analysed in the form $m + n \cos \delta$, then the resulting corrections to the 6-inch observations will be less than $0''\cdot 1$ at the pole. The form $m + n \cos \delta$ was accordingly adopted for the Second Cape Catalogue, a choice which was confirmed by comparison with the 9-inch catalogue. Furthermore, on forming the differences between the corrected 9-inch and corrected First Cape catalogue, the corrections being of course made according to both forms, it was found that the differences were decidedly smaller when the $m + n \cos \delta$ form was applied to the First Cape Catalogue. This form was accordingly adopted. From a further similar discussion of the difference between the catalogues the $m + n \cos \delta$ was adopted for the 9-inch Washington catalogue and the $x + y \sin z$ form for the 6-inch.

In order that the reader may gain some idea of the orders of magnitude involved, the systematic corrections obtained by Erichelberger to the four catalogues discussed will not be given.

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[1] The Washington refractions were determined from observations of circumpolar stars.

To the First Cape Fundamental Catalogue for the equinox 1900 correction $= -0''\cdot22 + 0''\cdot54 \cos\delta - 0\cdot15 \tan zn$.

To the Second Cape Fundamental Catalogue for the equinox 1900 correction $= -0''22 + 0\cdot''77 \cos\delta - 0\cdot15 \tan zn$.

To the Washington 9-inch observations correction $= +0''\cdot20 + 0''\cdot26 \sin zs$.

To the Washington 6-inch observations correction $= -0''\cdot48 \cos\delta$.

In these formulæ δ denotes declination, *zn* zenith distance north, and *zs* zenith distance south.

By a procedure which is in effect a comparison between the four corrected catalogues and Bors's catalogue, Eichelberger obtains the proper motions of the 1,504 stars discussed. These proper motions are printed in the catalogue which forms the main part of the volume in the form of corrections to Bors's proper motions. These corrections are tabulated for every 10° of declination. The results show a general kind of accordance with Kapteyn's suggested $k \cos\delta$ correction, this value of k being about 0″·010 per annum. Kapteyn's value of k was 0″·013 per annum. In Eichelberger's results there seems to be a tendency for the maximum correction to come somewhat south of the equator.

The above account of Eichelberger's discussion has been concerned only with declinations. Eichelberger also discusses the right ascensions. By straightforward comparison of the four catalogues he obtains the corrections necessary to reduce each catalogue to the mean of the four. Corrections to the right ascensions of Bors's catalogue and to Bors's proper motions in right ascension are given.

In an appendix to the volume the proper motions obtained by Eichelberger are discussed for solar motion. The declination of the solar apex obtained is + 20°·5, which is 14° smaller than the declination obtained by Bors and 5° smaller than the declination obtained by Campbell from his discussions of line of right velocities. The probable errors of Eichelberger's and Campbell's values are ± 1·7 and ± 1·8, so that it cannot be definitely stated that the difference of 5° is not accidental. Eichelberger's value for the right ascension of the apex is 265°·2 ± 1·9, which may be compared with Bors's value of 270·5 ± 1·5 and Campbell's value of 268°·5 ± 2·0.

Sir Frank Dyson and R. T. Cullen, in *Monthly Notices*, vol. lxxxiv, No. 7, May 1924, have discussed the declinations of the Greenwich observations for 1915–21. These observations were reduced to the epoch 1925·0, with Newcomb's precessions and Bors's proper motions, or, for stars not in Bors's catalogue, with Nyren's proper motions revised at

Greenwich by the addition of recent Greenwich and Cape observations.

As pointed out above, one of the sources of systematic error in observed declinations is flexure of the transit circle. This should lead to an error varying as the sine of the zenith distance, and may be determined by observing the horizontal flexure with the aid of the collimators. It may also be determined by observing stars in the ordinary way and reflected in a trough of mercury. Unfortunately, at Greenwich the flexure as determined with the collimators is nearly insensible, whereas differences are always found between direct and reflected observations. Furthermore, these differences do not appear to depend on the sine of the zenith distance, but rather they seem to be proportional to the tangent of the zenith distance. On making the best fit of the differences to a formula $a + b \sin z$, the values $a = +0''\cdot155$, $b = +0''\cdot69$ are obtained.

The observations were actually reduced with a flexure correction of $0''\cdot60 \sin z$, with Pulkovo refractions, and with co-latitude $38°31'21''\cdot90$, these being the corrections with which recent Greenwich catalogues have been reduced. This seems to be justified by the sun observations, which, as has been pointed out, determine the error at the equator. On forming the quantities tabular-observed for the observations of the sun's declination the mean comes out to be $-0''\cdot01$.

Dyson and Cullen proceed to compare the observations with those published in the Second Cape Catalogue for 1900, consisting of observations made in the years 1912–16. There are over 1,200 stars common to the two catalogues. The differences of declination in the sense of Greenwich–Cape were formed for every 5° of declinations. The gradient of these differences below the equator suggest that the Greenwich refractions need to be slightly increased for the southern stars. The observations of circumpolars, on the other hand, show that such an increase is inadmissible for stars north of the zenith. Dyson and Cullen conclude that the refraction at Greenwich is greater in the south than in the north—a conclusion which is quite reasonable when the local topography is considered. A correction of $+0''\cdot10 \tan z$ is needed for the southern stars in order to straighten out the differences Greenwich–Cape. The application of such a correction, however, reduces the declinations of the sun by $0''\cdot16 \sin z$. To put this right an alteration in the coefficient of the flexure term $0''\cdot60 \sin z$ is necessary.

From this and other considerations Dyson and Cullen conclude that the best results will be obtained by adopting a flexure correction of $0''\cdot50 \sin z$, and Pulkovo refractions with an additional $0''\cdot10 \tan z$ for the south stars only.

Taking the co-latitude to be 38°31′21″·80, and applying the above corrections, a comparison is made with the 1915 Pulkovo catalogue, with the *Berliner Jahrbuch*, with *The American Ephemeris* for 1925 (with the corrections given there) and with Bors's catalogue. The results show that the Greenwich observations are in general agreement with the *Berliner Jahrbuch* in taking a middle position between Bors and *The American Ephemeris.*

In each of these comparisons there is a discontinuity at the Greenwich zenith, at present unexplained.

In the above discussion by Dyson and Cullen the corrections to the declinations deduced from observations of the sun came out to be + 0″·01. This correction is, as has been pointed out, applicable to declinations reduced with co-latitude 38°31′21″·90, with flexure 0″·60 sin z and with Pulkovo refractions. The correction at the equator can also be determined from observations of planets, and in the same number of the *Monthly Notices* J. Jackson discusses the Greenwich observations of Venus for the years 1915–23.

Jackson converts the observed declinations and right ascensions of Venus into longitude and latitude. The declinations had been previously reduced with the above values of the co-latitude, flexure, and refraction. He differences the resulting values of the latitude and longitude from the tabular values in the Nautical Almanac. Analysis of these differences yield corrections to the equatorial declinations to the adopted right ascensions of the clock stars, and to the orbital elements of the earth and Venus.

From the discussion of the differences in longitude the correction to the right ascensions comes out to be $-0^s{\cdot}058 \pm 0^s{\cdot}012$.

From the discussion of the differences in latitude the correction to the equatorial declinations comes out to be + 0″·08 ± 0″·03.

A further discussion of the differences between the observed declinations and the tabulars gives the correction to the equatorial declinations as + 0″·18 + 0″·04.

Jackson also gives a short discussion of the comparatively few observations of Mercury available. The correction to the equatorial declinations comes out to be + 0″·06.

The accounts given above should give the reader some idea of the fascination attached to discussions of meridian observations. Eichelberger's discussion is of particular interest, especially that part of it which led him to adopt the cos δ in preference to the sin z correction in the cases of three out of the four catalogues discussed. An obvious criticism is that there is a physical reason for a correction of the latter form, to wit, flexure of the instrument, whereas no instrumental cause can be assigned to the cos δ correction. On the other hand, the figures certainly seem to be fairly decisive in favour of the cos c correction, the sin z correction to the record Cape Catalogue leading to an impossible correction to the Washington 6-inch observations in the neighbourhood of the pole. The matter will probably remain controversial for some time.

PHYSICS. By L. F. Bates, B.Sc., Ph.D., F.Inst. P., University College, London.

Recent Advances in Magnetism.—Our present knowledge of the nature of magnetism certainly leaves much to be desired, but it is of interest to consider some recent experiments, which bid fair to assist us in our interpretation of magnetic phenomena. The difficult and important researches of Gerlach and Stern must first be considered. The theoretical basis of these experiments is given by Stern (*Zeit. für Physik*, vol. 7, p. 249, 1921). According to the quantum theory, the vector of the moment of momentum of an atom situated in a magnetic field can only make a discrete angle with the direction of the field, such that the component of the moment of momentum in the direction of the field is an integral multiple of $h/2\pi$, (*vide* Sommerfeld, *Atomic Structure and Spectral Lines*, English Translation, p. 242). In general, with atoms whose total angular momentum is $nh/2\pi$, only $2n$ discrete positions are possible, since, according to Bohr, the position of the atom in which the vector of angular momentum is perpendicular to the direction of the magnetic field must be excluded. Thus, for an atom whose total angular momentum is $h/2\pi$, only two discrete positions are possible, λ for the components of the vector of the angular momentum in the direction of the field have only the two values $\pm h/2\pi$; *e.g.* single hydrogen atoms and single quantum atoms, on Bohr's conception, would have the planes of their orbits perpendicular to the field. Although this spatial quantisation in a magnetic field gives a simple interpretation of the Zeeman effect, there are several difficulties in the way of its acceptance. For example, it would be expected that a gas placed in a magnetic field would exhibit double refraction phenomena, and of this we have no experimental knowledge; in fact, Gerlach and Stern showed in the case of sodium vapour that magnetic double refraction does not exist. However, if on the above theory we consider a single quantum atom placed in the non-homogeneous field of a powerful electromagnet, the atom should experience a force which could only act upon it in one of two possible directions. Gerlach and Stern, in their experiments, used a wedge-shaped pole piece, and they caused a stream of metallic atoms, vaporised in a specially designed electric oven, to be projected through a narrow slit, so that they moved parallel and close to this wedge *in vacuo*. On the above theory, if the atoms were single quantum atoms, this stream should be resolved into two definite bands, whereas, if the magnetic axes of the atoms were orientated in all directions only a broadening of the stream would occur. A knowledge of the distance between two such bands, and the constants of the magnetic field, would enable us to calculate the value of the magnetic moment of the atoms. A clear description of the general arrangement of the apparatus used is given in the *Annalen der Physik*, vol. 74, p. 677, 1924. In the earlier experiments, beams of silver atoms were used, which, after traversing the magnetic field, fell upon a carefully cleaned strip of plate glass and formed invisible deposits of silver thereon. These deposits were rendered visible by repeated development with dilute silver nitrate solution (1 per cent.) to which was added ½ to 1 per cent. of hydroquinone solution, not too fresh, and a large quantity of gum-arabic. The silver atoms were found to be spread out into two bands, one being deflected towards the wedge, and the other away from it, and there were no undeviated atoms in the region between the two bands. This has been interpreted as a direct proof that the silver atom possesses a magnetic moment, and that spatial quantisation of atoms takes place in a magnetic field. In a more recent communication (*Annalen der Physik*, Feb. 1925) a more detailed description of apparatus and results with other atoms are given. It was found that some metals gave visible deposits, which were of the same form as the developed silver deposits, and deposits of other metals could be developed or intensified in the same way. Silver, copper, and gold were found to possess magnetic moments of the order of one Bohr magneton, whilst zinc, lead, antimony, bismuth, and iron showed no effect ; yet nickel gave a rather complicated deposit, produced by such very powerful action of the field on the nickel atoms that some were drawn into the pole piece and others were sent away until they entered a field whose intensity varied so little from place to place that they continued to travel parallel to the edge of the wedge without further deviation. The difference in the behaviour of nickel and iron seems very remarkable.

In connection with these experiments, mention must be made of the difficulties which attend their interpretation, and, in particular, reference may be made to a paper by Einstein and Ehrenfest (*Zeit. für Physik*, vol. 11, p. 31, 1922), who discuss the method by which the silver atoms in these experiments obtain their discrete orientations. They point out that the atoms suffer no collisions in the deflecting magnetic field, and as long as the emission and absorption of radiation, collisions, etc., are excluded, the atoms will perform a Larmor precession about the direction of the magnetic field. If, then, the direction of the field changes slowly with respect to the speed of the precession motion, the angle of precession will be constant, and a deposition of the silver atoms on the glass plate cannot take place in the manner required by the quantum theory, unless effects due to radiation and to atomic collisions are present. However, even admitting the influence of radiation at room temperature in the deflecting chamber, it is found that the time required to enable an atom to take up a definite orientation would be of a totally different order of magnitude to that actually required to account for the experimental results. To avoid these difficulties, two alternate assumptions are made ; viz. : (*a*) The effective mechanism is such that the atoms never are in a state in which they are not fully quantised spatially ; or, (*b*) The orientations demanded by the quantum theory are produced by gain and loss of radiation with a velocity of reaction infinitely greater than that of the change from quantum to non-quantum states. The characteristic differences and difficulties which arise from these two assumptions are discussed and used to show how unsatisfactory are the conclusions drawn from the Gerlach and Stern experiments.

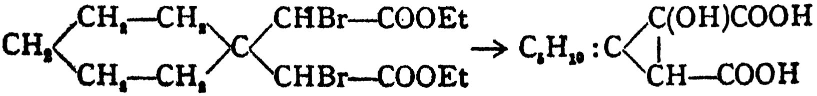
Ruark and Breit (*Phil. Mag.*, Feb. 1925, p. 504) point out that the Gerlach and Stern experiments only give information of the component of the magnetic moment of the atom parallel to the direction of the field. Now, Bohr's model of the helium atom requires that it should be paramagnetic, whereas helium gas is diamagnetic. Bohr, therefore, assumes that the spatial quantisation of normal helium is such that the atoms are directed with their axes of angular momentum perpendicular to the field, so that there is no positive contribution to the susceptibility, and the gas is diamagnetic. A Gerlach and Stern experiment, if it were successful and showed no deflection of a stream of helium atoms, would not decide between Bohr's conception and the view that the helium atom has no residual magnetic moment, and can thus take up any orientation with respect to the field. However, if the helium atoms are orientated in a magnetic field, as above, then the gas should possess a different dielectric constant, according as the applied electric field is parallel or perpendicular to the applied magnetic field, and Ruark and Breit propose to test this experimentally.

Glaser has recently described (*Annalen der Physik*, vol. 75, p. 459, 1924, and *Physikal. Zeit.*, vol. 26, p. 212, 1925) a very sensitive experimental arrangement for the examination of the magnetic susceptibility of a gas at various pressures. He suspended a small glass cylinder from a torsion head inside a chamber placed between the poles of an electromagnet, by means of a fine quartz fibre. The cylinder was made of two kinds of glass, so that it was slightly paramagnetic. In the chamber the gas under investigation was stored at various pressures, and the angles through which the torsion head was turned in order to restore the cylinder to a fixed position of equilibrium were measured, a constant magnetic field being maintained between the poles of the electromagnets. These angles were measures of the differences in susceptibility of the cylinder and the surrounding gas at these pressures. Great care was taken to keep the chamber and its contents at a constant temperature. A series of curves representing the relations between the susceptibility and the pressure for highly purified carbon dioxide, hydrogen, and nitrogen were thus obtained. On the classical theory the susceptibility of a given gas should be directly proportional to its pressure. However, it appears from these curves that at high pressures the diamagnetic susceptibility of a given volume of a gas is directly proportional to the pressure, but around a certain value of the pressure, which value differs for the several gases, this simple relation ceases to exist, and the diamagnetic susceptibility then decreases much more slowly over a range of pressure values, until eventually the diamagnetic susceptibility of a given volume again decreases linearly to zero with the pressure, but at a much greater rate than before. Glaser has suggested that these features may be explained on the assumption that at the lower pressures the molecules have larger mean free paths, and the time between molecular collisions becomes sufficiently great to permit them to take up definite orientations with respect to the magnetic field, as required by the quantum theory, and consequently, when the pressure of the gas is sufficiently low, the molecules may be regarded as completely orientated in a definite direction, and the susceptibility per unit volume again becomes directly proportional to the pressure. It should be noted, however, that this explanation is by no means satisfactory; *e.g.* Pauli (*Physikal. Zeit.*, vol. 26, p. 217, 1925) has pointed out that for the large majority of the molecules of the gases investigated under the temperature conditions of the experiments, the total quantum numbers, and therefore, the numbers of possible orientations, are so large that the molecules might almost be regarded as orientated in all directions. Glaser himself emphasises the need for further experimental work under widely different conditions of field and temperature, and such work is now in progress.

In connection with the diamagnetism of gases a short theoretical paper by S. J. Barnett (*Phys. Rev.*, June 1925) is of interest. He discusses Weber and Langevin's theory of diamagnetism, and also that of Pauli (*Zeit. für Physik*, vol. 2, p. 201, 1920), and shows that Glaser's experimental result, viz. that the diamagnetic susceptibility at low pressures may be three times the expected value on the classical theory, could not be predicted from Pauli's unmodified theory, which applies only to monatomic gases, and could be accounted for on the Weber-Langevin theory only by assuming all the electron orbits in the atom to be coplanar, which is far from probable, and by assuming complete alignment, a reason for which is not clear. In discussing the alignment of diamagnetic molecules, Barnett points out that the expression derived by Langevin for the alteration of the susceptibility with alignment indicates that, even with the most intense fields available, the effects must be extremely minute, except at a temperature near absolute zero, and the theory cannot account even qualitatively for Glaser's results. There is clearly much need for fundamental magnetic experiments, particularly on the diamagnetism of gases.

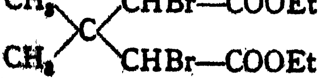
ORGANIC CHEMISTRY. By O. L. Brady, D.Sc., F.I.C., University College, London.

Ring-chain Tautomerism.—If the carbon atom occupies the centre of a regular tetrahedron, and the four valencies are directed towards the corners, the angle between any two adjacent valencies is 109°–28′. Thorpe and his co-workers (*J.C.S.*, 1915, **107**, 1080 *et seq.*, see also this Journal, 1921, **16**, 14) have, however, shown that if the angle between two valencies be altered by their participation in ring formation, or by their attachment to groups, the remaining angles will be changed in consequence. The criterion employed to test this idea was the ease of formation and stability of ring compounds. As might be anticipated, where the two valencies were in the cyclo hexane ring, it was found that treatment of the dibromo ester [i] with potash gave the hydroxy ring acid [ii]:

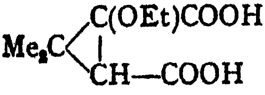


[i] [ii]

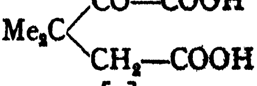
where, however, they were attached to methyl groups, treatment of the dibromo ester [iii] with aqueous caustic potash gave the ethoxy compound [iv] and the keto acid [v] in its hydrated form :



[iii]



[iv]

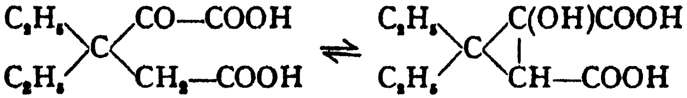


[v]

(The alkyloxy derivatives are hydrolysed by hydriodic acid to the keto acid [*J.C.S.*, 1923, **123**, 1207]).

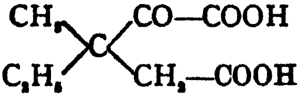
Thus the effect of the cyclo hexane ring is seen in the stability of the hydroxy ring acid, while with the gem-dimethyl groups the keto acid is stable.

Experiments have now been carried out to find the effect of different groups on the formation of the hydroxy ring acid and the keto acid, and in the case of the gem-diethyl group (Deshapande and Thorpe, *J.C.S.*, 1922, **121**, 1430) it has been found that both compounds can be obtained, and that they are tautomeric—that is to say, a 64 per cent. aqueous solution of potassium hydroxide will convert either into an equilibrium mixture of 38 per cent. of the keto acid [vi] and 62 per cent. of the hydroxy ring acid [vii].



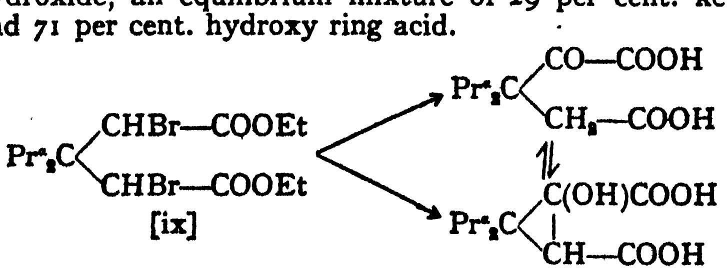
[vi] [vii]

Singh and Thorpe (*J.S.C.*, 1923, **123**, 113) found that in the case of the methyl ethyl groups, the keto acid [viii] was obtained and was stable to a 64 per cent. aqueous solution of potassium hydroxide :



[viii]

Bains and Thorpe (*J.C.S.*, 1923, **123**, 1206) found that in the case of the gem-di-n-propyl group, the dibromo ester [ix] gave a mixture of the keto acid [x] and the hydroxy ring acid [xi], and that these gave, in 60 per cent. aqueous potassium hydroxide, an equilibrium mixture of 29 per cent. keto acid and 71 per cent. hydroxy ring acid.

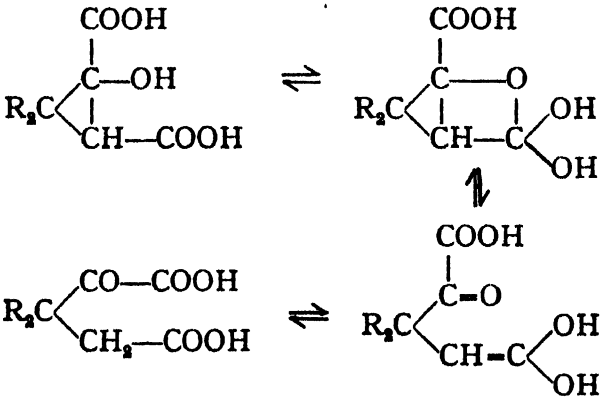


[ix] [x] [xi]

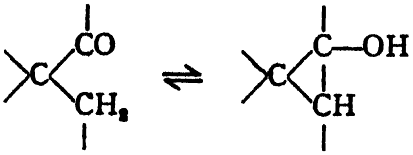
These results may be summarised :

	Equilibrium.	
	Per cent. keto acid.	Per cent. hydroxy ring acid.
2 Methyls	100	0
Methyl ethyl	100	0
2 Ethyls	38	62
2 n-Propyls	29	71
cyclo Hexane	0	100

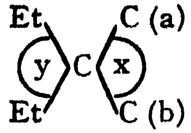
The cyclo pentane derivatives have been found similar to the dimethyl derivatives in their general reactions, Lanfear and Thorpe (*J.C.S.*, 1923, **123**, 1683). When, however, the dibromo compound was treated with potassium hydroxide, a hydroxy ring acid could be obtained which hydrobromic acid converted to the keto acid. The reason for this difference of behaviour to the dimethyl derivative is that the hydroxy ring acid is a *cis* form whilst the other hydroxy acids from, for example, the diethyl compound, are *trans* forms, and it is the latter which undergo fission with alkali. Thus the instability must be due to the hydroxyl and carboxyl groups being on the same side of the ring, and the change, keto acid ⇌ hydroxy ring acid, may be represented :



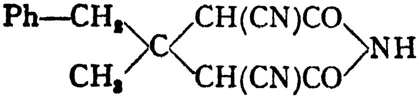
In these compounds, it is therefore possible to realise the necessary conditions, such that the following ring-chain tautomerism comes into play :



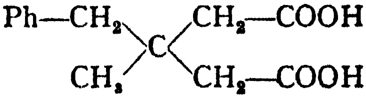
The molecular volumes of the gem-diethyl and the gem-di-n-propyl groups are such that the angle *y* is made greater than the tetrahedral angle $2 \tan^{-1}\sqrt{2}$, and less than 120°, the cyclo hexane angle. In consequence the value of the angle *x* is decreased to between 107°·2 and 109°·5, the values in the cases of the cyclo hexane and dimethyl derivatives, and so the carbon atoms *a* and *b* are at such a distance apart that the two forms, keto acid and hydroxy ring acid, are tautomeric. This ring-chain tautomerism may be compared with the ordinary keto-enol tautomerism, $R—CO—CH_2— \rightleftharpoons R—C(OH) = CH—$.



Another interesting case of ring-chain tautomerism is the following : when the ω-imide of $\alpha\alpha'$-dicyano-β-benzyl-β-methyl glutaric acid [xii] (Kon and Thorpe, *J.C.S.*, 1919, **115**, 704), prepared by condensing benzyl methyl ketone with ethyl cyano-acetate in alcoholic ammonia, was hydrolysed, it did not give the expected β substituted glutaric acid [xiii]

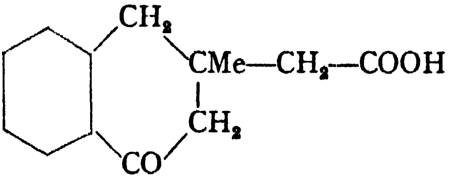


[xii]



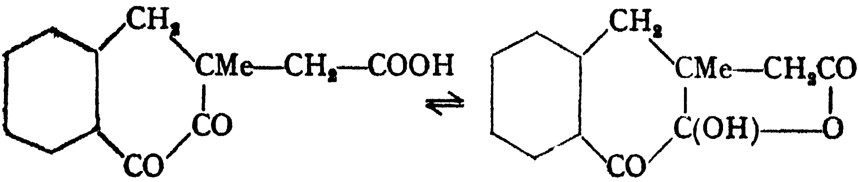
[xiii]

Later, Kon and Stevenson (*J.C.S.*, 1921, **119**, 87) found that the product of hydrolysis was the tetrahydronaphthalene derivative [xiv] :



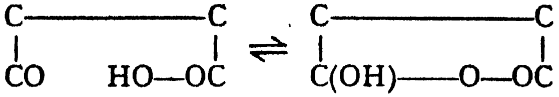
[xiv]

When the compound [xiv] was treated with a 1 per cent. solution of potassium permanganate in sodium hydroxide, a compound was obtained which has been found to react in the two forms [xv] and [xvi] (*ibid.*, 1922, **121**, 650) :

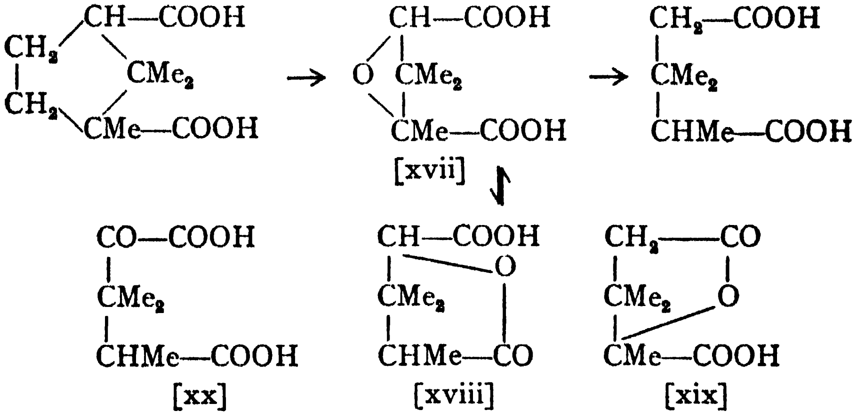


[xv] yellow. [xvi] colourless, m.p. 171°.

It gives an acetyl derivative in accordance with [xvi] and with *o*-phenylenediamine, a quinoxaline, which is a monobasic acid, in accordance with [xv]. The colourless compound m.p. 171° gives a colourless solution in alcohol or water. When the solution is warmed, a yellow colour appears, and this disappears on cooling. A similar result is obtained using benzene as a solvent. It is therefore suggested that the compounds exhibit ring-chain tautomerism, the diketo form being yellow:



Another substance investigated is the acid $C_8H_{12}O_5$, which was obtained by Balbiano by oxidising camphoric acid. (*Rend. Accad. Lincei*, 1892, **1**, 278; *Ber.*, 1894, **27**, 2133). Balbiano reduced this to an acid $C_8H_{14}O_4$, which Perkin and Thorpe showed to be *aββ*-trimethyl glutaric acid (*J.C.S.*, 1899, **75**, 61). Balbiano suggested the oxide formula [xvii] for his acid $C_8H_{12}O_5$. He reduced it to a lactonic acid [xviii] which could be oxidised back to the original acid.



[xvii] [xx] [xviii] [xix]

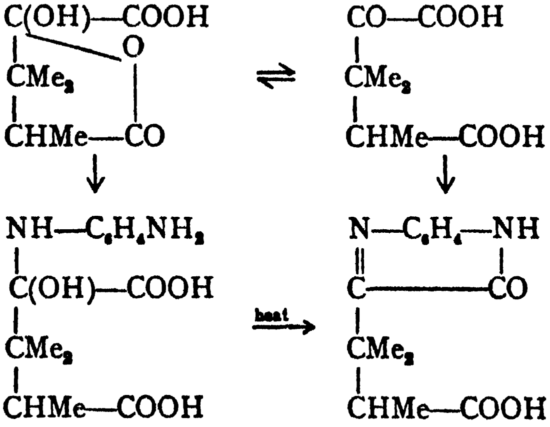
Balbiano, m.p. 163° Blanc, m.p. 163°
R., S., and T., m.p. 165°·5.

Blanc (*Bull. Soc. Chim.*, 1901, **25**, 68) prepared an isomeric lactonic acid m.p. 163°, which must have the structure [xix] as it was prepared from dimethyl lævulic acid, by addition of hydrocyanic acid and hydrolysis. Balbiano then re-examined his reduction product, and states that he prepared from it, by separation of the barium salts, two lactonic acids m.p. 163° and m.p. 165°. Blanc states that Balbiano's lactonic acid depressed the melting point of his lactonic acid to about 115°. Balbiano, with a mixture of the lactonic acids prepared by him, found that the melting point was depressed only 5°, and concluded that he had prepared both lactonic acids [xviii] and [xix] from his acid, and that therefore the oxide formula [xvii] was correct.

Mahla and Tiemann (*Ber.*, 1895, **28**, 2151) suggested that Balbiano's acid was *a′*-keto-*aββ*-trimethyl glutaric acid [xx]. On heating it was converted into carbon monoxide and trimethyl succinic anhydride. They prepared derivatives with hydroxylamine and *p*-bromophenyl hydrazine. Balbiano (*Ber.*, 1897, **30**, 289) showed that the latter was an addition product and not a hydrazone.

The whole question of the structure of this acid has now been completely re-examined (Kon, Stevenson, and Thorpe, *J.C.S.*, 1922, **121**, 650; Pandya and Thorpe, *ibid.*, 1923, **123**, 2852; Rothstein, Stevenson, and Thorpe, *ibid.*, 1925, **127**, 1072). Both the lactonic acids have been obtained from the monobromination of *αββ*-trimethyl glutaric acid. A mixture of the two, melted at 115°, confirming Blanc's statement. Blanc's lactonic acid has been synthesised again, and it has been shown that it is not prepared by the reduction of Balbiano's acid. It is suggested that Balbiano's acid exhibits ring-chain tautomerism, and reacts in the two forms [xxi] and [xxii].

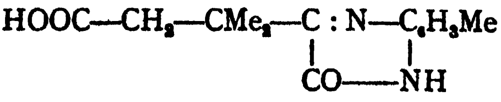
[xxi] [xxii]



[xxiii] [xxiv]

Perkin and Thorpe found that the best reagent for the identification of *α*-keto-*ββ*-dimethyl glutaric acid was o-tolylenediamine, which gave a condensation product [xxv]:

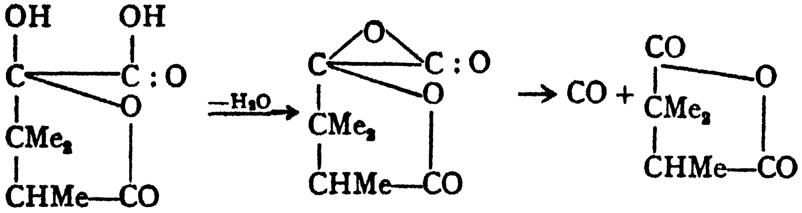
[xxv]



o-phenylenediamine has now been found to give a similar product.

When Balbiano's acid was treated with *o*-phenylenediamine, an addition product [xxiii] and a condensation product [xxiv] were obtained, suggesting that the acid was reacting in two forms. When the addition product was heated above its melting point, it passed into the condensation product and water.

The formation of carbon monoxide and trimethyl succinic anhydride from the hydroxy lactone [xxi] on heating, may be explained thus :



The above examples indicate the general ideas on this subject brought forward by Thorpe and his co-workers. The conception has also been applied to the Mutarotation of the Sugars (Baker, Ingold, and Thorpe, *J.C.S.*, 1924, **125**, 268), Cyanobenzoic acid (Dickens, Horton, and Thorpe, *ibid.*, p. p. 1830), and to the Fluoresceins and Rhodamines (Dutt and Thorpe, *ibid.*, p. 2524).

GEOLOGY. By G. W. TYRRELL, F.G.S., A.R.C.Sc., Ph.D., University, Glasgow.

Mechanism of Intrusion and Tectonics.—Within recent years there has arisen a new school of interpretation of the relation between igneous masses, especially granite, on the one hand, and orogenetic pressure and tectonics on the other. This movement is headed by Prof. Hans Cloos of Breslau, and dates from his investigation of the tectonics and intrusion-mechanism of the Erongo granite of ex-German South-West Africa (*Beitr. zur geol. Erforschung der Deutsch Schutzgeb.*, Heft 17, Berlin, 1919), followed by intensive work on the granite masses of Eastern Germany. His methods have been taken up enthusiastically by many German, Austrian, and Scandinavian geologists. Cloos' principal works are the following: "Der Mechanismus tiefvulkanischer Vorgänge" (*Sammlung Vieweg*, Heft 57, Braunschweig, 1921). "Tektonik und Magma. Untersuchungen zur Geologie der Tiefen" (Bd. 1, *Abhandl. d. Pr. Geol. Landesanst. N.F.*; 89, Berlin, 1922. Bd. 2, 1923). *Der Gebirgsbau Schlesiens und die Stellung seiner Bodenschätze* (Gebr. Bornträger, Berlin, 1922). *Einführung in der tektonische Behandlung magmatischer Erscheinungen* (*Granittektonik*), 1, Spez. Teil. Reisengebirge in Schlesien (Gebr. Bornträger, Berlin, 1925, pp. 194). Excellent reviews and summaries have been given by S. von Bubnoff ("Die Methode der Granitmessung und ihre bisherigen Ergebnisse," *Geol. Rundsch.*, **18**, 1922, pp. 151–70), and H. Reck (Review, *Zeitschr. f. Vulk.*, Bd. 8, Heft 1, 1924, pp. 38–72).

The fundamental observation of Cloos is that granitic intrusion almost always takes place under directed pressure, which leaves its distinctive marks on both solid and plastic phases of the igneous rock. He makes a sharp distinction between concordant and discordant massifs. The borders of concordant massifs run parallel to the strike and elongation textures of the framing rocks. Such massifs are little suited for the determination of the general pressure direction, for, as they were intruded during orogenic deformation, the enclosing frame itself was more or less plastic, and the directional features produced in the granite indicate only the movements of the frame. But when the orogenic block is stiffened by folding and intrusion it is able to transmit the general pressure undeviated, and the directional features produced in the solid igneous rock now occur according to the mechanical laws of solid, not semi-plastic, masses. The features are determined by fracture-tectonics, not fold-tectonics. A newly intruded massif at this stage does not follow the strike of the older folding, but room is made for it according to the fracture-tectonics of solid bodies; it breaks across fractures and joint-planes and becomes a discordant massif.

Hence the directional features in granite may be divided into those impressed during the plastic phase and those impressed in solid phase. Amongst the former are foliation (the least valuable for pressure determination, as it depends on so many other factors, such as local pressure of the frame, load, etc.), flow-banding and schlieren, and the linear streaking (Streckung) shown by the parallelism of columnar, acicular, or flaky minerals. The solid phase features are the potential fracture directions of rift and grain, joints, diagonal fissures, and dykes. All these directions are shown by Cloos to be mathematically related, and to be orientated with reference to the directions of pressure prevailing during and after the intrusion and consolidation of the granite.

Directed pressure thus does not cease with the consolidation of the granite; a semi-plastic reaction is merely succeeded by a brittle reaction. This deduction from the related orientation of the two sets of directional features has an extremely important bearing on the ages of foliated and unfoliated granites where these occur together, as in the Dalradian area of the Scottish Highlands. Cloos has remarked on the mineralogical and chemical similarity, and even identity, between similarly related German granites. Obviously foliation in such granite masses may be no criterion of totally different age to the associated unfoliated granite; and if the directional features in each can be shown to be closely related, a close association in time is also indicated.

In regard to the origin and emplacement of batholiths Cloos has been led to views diametrically opposed to those of Daly ("Das Batholithenproblem," *Fortschr. d. Geol. und. Pal.*, Heft 1, 1923, 80 pp.). Daly believes that magmas are active agents in making room for themselves by stoping and assimilation. Cloos, on the contrary, gives reasons for believing that the spaces occupied by batholiths are tectonically made by thrusting upwards, laterally, and even downwards, of the enclosing rocks, and that the magma is passively squeezed into place. Stoping, inclusions of country rock, and assimilation, are to him merely " by-product " phenomena. Furthermore, field study of the German granites shows that they have been injected between the country rocks, and are therefore not "bottomless." Concordant massifs have roofs and floors determined by structural and foliation planes. Discordant massifs differ from laccoliths only in that their upper margins are determined by major joint fractures which cross-cut the structural features of the country rocks, and thus bring about discordant junctions. These ideas are very little removed from those expressed by Iddings in his last book, *The Problem of Vulcanism*, 1914.

Just as, when the general succession of fossils in the geological record was first ascertained, this succession was used in its turn to solve stratigraphical problems, so the intensive study of directional features in granite masses has thrown new light on the tectonics of the regions in which they occur. Thus Cloos and his co-workers, von Bubnoff in particular, have reached important new conceptions in regard to tectonic conditions in the Northern Alps, where they are opposed to the Hercynian blocks of South and Eastern Germany. The tectonics of the Hercynian blocks themselves have been further elucidated. Although Cloos, in his enthusiasm, may have somewhat overstepped his facts, and strained his theories, there can be no doubt whatever that his methods have been and will be extremely fruitful in results in the tectonic field, and in regard to modes of plutonic intrusion.

The structural relations of the great igneous complex of the Bushveld (Transvaal) have been studied by Profs. R. A. Daly and G. A. Molengraaf (*Journ. Geol.*, 32, 1924, pp. 1–35). This enormous mass, an erosion remnant still 500 kms. long by 150 kms. wide, has lopolithic relations to its floor, but, on account of the number of different units involved, it is best called a complex pending further knowledge. The magma, originally basic, seems first to have produced thick sills in the strata of the Transvaal System, but most of it broke right through and differentiated as a basal mass of norite surmounted by granophyre-felsite. The characters of the latter appear to indicate actual welling-out at the surface; and it thus illustrates areal or de-roofing eruption on a grand scale. Both phases were later penetrated by dykes, sheets, and stocks of coarse granite, the last phase of the igneous invasion. The whole episode shows thorough differentiation dominated by the gravity field.

G. R. MacCarthy has made a study of laccolith formation by experimental methods (*Journ. Geol.*, **33**, 1925, pp. 1–18). Artificial strata of alternate layers of plaster and wet sand were injected from beneath by a plaster mixture coloured in various ways. The shapes and relations of the resulting "intrusions" revealed some interesting features. It was shown that the more viscous the "magma" the greater the vertical as compared with the lateral extent of the intrusion produced; and conversely, the thinner the magma, the more sill-like the intrusion. Increasing viscosity during intrusion intensified the effects of stiff magmas, and bysmaliths or stocks were produced rather than laccoliths. Excessive speed of intrusion led to the same development.

The intrusion mechanism of large dykes, as exemplified by the Medford dyke in Eastern Massachusetts, has been studied by M. P. Billings (*Journ. Geol.*, **33**, 1925, pp. 140–50). The Medford dyke is associated with cross-dykes belonging to at least seven systems. Detailed mapping shows that these dykes have not been offset by the intrusion of the big dyke, as they should have been had its intrusion taken place by the rending apart of the walls of a fissure. This suggests that the Medford dyke made room for itself by some process of stoping; and, since piecemeal removal of the country rock is not a satisfactory solution, the hypothesis of large-scale block stoping is put forward. The whole mass of rock displaced by the dyke is believed to have sunk downwards *en masse* in the rising basaltic magma.

Vulcanology.—In a fine detailed study of the Vesuvius eruption of 1906, illustrated by many magnificent plates, Mr. F. A. Perrett (*Carn. Inst. Washington, Publ. No.* 339, 1924, 151 pp.) emphasises the cyclical nature of eruption at this focus. There is an accumulation of energy during a long repose period, followed by its paroxysmal release in a short eruptive spasm. Thus there was a gradual rise of the lava column prior to the 1906 eruption. A highly gas-charged, potentially-explosive magma develops deep down in the closed conduit, and eruption occurs when some factor disturbs the state of equilibrium which obtains. The fissuring of the south wall of the cone "pulled the trigger" of the 1906 eruption by permitting the escape of the uppermost magmatic layers, and releasing the explosive magma below.

The actual eruption is divided by Perrett into three phases: the initial luminous lava phase, the intermediate gas phase, and the final dark ash phase. The second of these phases is described as a continuous powerful emission of gas, like a boiler "blowing off," which lasted for many hours, and produced a column of vapour 11 kms. high.

Many other interesting features are described, including the fluent lava and its various forms; the solid ejectamenta; hot avalanches of volcanic sand at high temperatures; the subsequent degradation and collapse of the crater; and the actual refusion of old lava by new magma.

The explosive eruption of Kilauea in May 1924 is described by T. A. Jaggar and R. H. Finch (*Amer. Journ. Sci.*, (5), **8**, 1924, pp. 353–74). Since 1920, the culminating year of the present "nine year cycle," there has been a decline in intensity punctuated by strong collapses at the Halemaumau lava pit. Subsidences of the lava were phenomenally strong in November–December 1919 and May 1922, the latter leading to enlargement of the pit, and extraordinary avalanches resulting in cauliflower clouds of sand and dust. Similar collapses in May 1924 were on a still greater scale, and were accompanied by explosions throwing out broken rocks. Some wonderful photographs of the clouds are given. These eruptions form a remarkable repetition of the 1790 explosions at Kilauea, which, on account of the 130-year interval discerned by Omori, Wood, and Jaggar, have led the Hawaiian investigators to watch the years about 1920 with especial interest.

During an interval of twenty-eight days in July–August, 1919, an almost continuous series of observations of the height of the lava in the Halemaumau pit was secured by E. W. Brown under the direction of Dr. T. A. Jaggar (*Amer. Journ. Sci.*, **9**, 1925, pp. 95–112). The analysis of the figures obtained shows some evidence of tides with the periods of the lunar day and half-day, with double amplitudes of an inch or so.

In a paper on the earth movements accompanying the Katmai (Alaska) eruption of 1912 (*Journ. Geol.*, **33**, 1925, pp. 116–39, 193–223), Dr. C. N. Fenner shows by analysis of seismometer records of stations over the whole northern hemisphere that tectonic earthquakes must have taken place, as well as volcanic quakes of some severity which are indicated by rock slides, etc. Distinct shocks were felt at points one hundred miles from the volcano. If these were volcanic quakes they would have been of extraordinary severity within the central region, but there is no evidence of this. It is only rarely that eruptions, large or small, are accompanied by tectonic earthquakes.

The origin of the fissures and faults in the Valley of Ten

Thousand Smokes, which gave rise to the great pyroclastic sand flow of that region (Science Progress, April 1924, p. 541) is discussed. It is believed that they were caused by the intrusion of a magma in the form of a sill at a small depth below the valley floor.

Eric Hülten describes the eruption of a small Kamtchatkan volcano (Ksudatch), said to have taken place on March 28, 1907, which threw out such a quantity of yellow pumice as to convert 250 sq. kms. into an absolute desert, and the dust of which was noted 600 kms. distant from the source (*Geol. För. Stockholms Förh.*, **46**, 1924, pp. 407–14). The amount of material erupted in the form of pumice, ash, and dust is estimated at 3,000 million cubic metres. Hence this must be accounted as one of the largest known ash eruptions.

Certain atmospheric phenomena in 1907, such as the increase of twilight glow, the appearance of Bishop's ring, the dislocation of the neutral points of the sky, and the decrease of sunlight, as well as the remarkable night-clouds and "white-nights" of 1908, are attributed to the presence of dust from Ksudatch in the atmosphere.

Prof. R. A. Daly's memoir on the geology of Ascension Island (*Proc. Amer. Acad. Arts and Sci.*, **60**, 1925, pp. 1–80, 21 pls.) gives many new vulcanological facts regarding that island. He estimates that there are no fewer than sixty vents of basaltic or trachytic composition. The basaltic lava masses and vents are classed as exogenous lava domes, fissure eruptions, lava cones, composite cones, and pyroclastic cones; the trachytic masses fall into two groups, endogenous domes or crater-fillings, not visibly affected by axial subsidence, and similar masses deformed by axial subsidence. He also makes some interesting observations on the modes of flow of basaltic lavas. Downstream, the "plastic-solid" crust is deformed by folding and thrusting over the still liquid interior of the flow; upstream, the crust is rent apart, causing wide rifts, at the bottom of which is the surface of the vitreous central part, showing a characteristic dentated surface of scission. As at Vesuvius (1906) streams of hot fluent lava have worn pronounced channels or gutters, often a metre in depth, in the older rocks.

Prof. Daly has also described some vulcanological features in his account of the geology of American Samoa (*Publ. No.* 340, *Carn. Inst., Washington,* 1924, pp. 95–143). The main island, Tutuila, is structurally an elongated exogenous dome essentially consisting of basalt lavas, which appear to have been emitted from fissures and from central vents aligned on the fissures, running nearly parallel to the long axis of the island. There are five small plugs of trachytic rocks, a small neck of mafic gabbro, and numerous basic dykes piercing the basalt lavas, which are predominantly of the blocky or aphrolith type.

A discussion on the temperatures of hot springs, and the sources of their heat and water supply was held at the annual meeting of the American Geophysical Union in April 1923 (*Journ. Geol.*, **32**, Nos. 3–6, 1924). It is not possible to mention even the titles and authors of the numerous papers given; but R. B. Sosman has contributed a very useful summary of the discussion (*Journ. Geol.*, **32**, 1924, pp. 468–71). It was shown that chemical reactions, such as can be inferred from the composition of spring waters, cannot account for more than a very small proportion of the heat. Neither can radioactivity. Adams and Morey, however, showed that heat may be developed by the forced flow of a fluid or steam through a porous plug; but data are lacking to show to what extent this action is operative in supplying heat. There was general agreement that the source of the heat in high-temperature springs and fumaroles is in sub-crustal rock magma, but the question as to how the magmatic heat becomes localised was perforce left open. It was also shown that the amount of water which may be dissolved in a batholithic magma may be sufficient to supply small hot springs for hundreds of thousands of years without any additions of surface waters. The conditions of crystallisation in such a magma might yield water vapour under considerable pressure.

BOTANY. By E. J. SALISBURY, D.Sc., F.L.S., University College, London.

Ecological.—The rôle of wind in relation to the distribution of arborescent vegetation is considered by Szymkiewicz (*Acta Soc. Bot. Polon.*, ii, 2). Data is furnished to show that high winds, combined with low temperatures, are incompatible with the growth of trees, and that such vegetation is replaced by tundra, heaths, etc., where there are glacial winds of a mean speed of 6 metres per second or upwards at a height of about 10 metres above the soil level. The changes in direction of the tree limit are attributed to this factor, as also the North German heaths.

A large number of cultures of wild species from different habitats have been made by Turessen, who finds that the races remain distinct when growing side by side under the same conditions. Thus, prostrate races from calcareous soils (ecotypes) are described for *Artemisia campestris*, *Rumex acetosella*, *Silene maritima*, etc. (*Hereditas*, vi, 1925). The view adopted is that the habitat effects a selection of the most favourable mutants. These latter become zoned in relation to climatic conditions so that different ecotypes inhabit the different climatic regions, and hence the potentiality for the development of derived ecotypes is also different. This is how the author explains the fact that alpine ecotypes are found in Scandinavia of *Melandrium rubrum*, *Ranunculus acer*, *Rumex acetosa*, and *Geum rivale*, but are not present in the Alps. Similarly, it is suggested, types may have been produced in the past geological periods, which once lost cannot reappear. The author proposes the use of terms such as *œcotypus alpinus œct. arenarius* to designate the parallel races of different species, thus avoiding the multiplication of varietal names.

From statistical studies of pollen from a number of localities in Ireland, Scotland, and Sweden, Erdtman finds that in the older peat of each of these areas there is a dominance of pine pollen (Sweden 61 per cent., Ireland 58 per cent., Scotland 30 per cent.) and birch pollen (Scotland 60 per cent., Sweden 30 per cent., Ireland 26 per cent.). Next in order of frequency comes the hazel (8 per cent. in all three regions), whilst *Quercus*, which attains 6·2 per cent. in Ireland, only constitutes 2·6 per cent. in Scotland. The alder ranges from 4·7 per cent. in Scotland to 5·5 in Sweden and 9·3 in Ireland (*Geol. Foren. Forhandl.* Bd. 46, p. 676).

The Hydrogen-ion concentration of the soil in a large number of stations for each of several species has been determined by Salisbury (*Jour. Ecology*, January 1925). When the *p*H values are plotted against frequency the " curve " for each species shows an approximation to a normal curve, but where the range extends over the neutral point a bimodal form is exhibited. The values for the modes are characteristic for the species, and in general the stations corresponding to extreme values are locations where the species is rare and the individuals less vigorous. The importance of soil reaction as a habitat factor is pointed out, producing as it does not only direct effects, but also largely determining the solubility of toxic salts of iron and aluminium. Attention is drawn to the inadequacy of any ratio of bases to explain the relations exhibited.

The results of a study of seventy-eight Sphagnum bogs on the Pacific coast of North America are described by G. B. Riggs (*Ecology*, July 1925). Their altitude varies from sea-level to 6,000 feet, and the depth of the peat from 1 to 30 feet. The most frequent Phanerogams are *Oxycoccus oxycoccus* and *Drosera rotundifolia*, but in addition mention may be made of the following as of special interest from their occurrence also in British Sphagneta : *Empetrum nigrum*, *Andromeda polifolia*, *Myrica gale*, *Vaccinium vitis-idæa*, *Rubus chamæmorus*, *Comarum palustre*, and *Pinguicula vulgaris*. The presence of dead conifers on the extending margins of these bogs, of stumps in the peat, and the encroachment of the bogs on the swamps are all consistent with the replacement of Forest by Sphagnetum owing to clogging of the natural drainage channels. In the same number A. B. Klugh describes a new method of estimating light intensity by means of panchromatic plates exposed beneath a graded set of filters which transmit different percentages of light without appreciably altering its special composition.

M. Denis (*Ann. d. Sci. Nat. Bot., T.* VII, No. 1), writing of the ponds in the Forest of Fontainebleau, states that all the available evidence shows that this area was more humid formerly and that the ponds were once more numerous—a conclusion identical in character with that arrived at by the reviewer from a study of the changes in the Flora of Hertfordshire (*Trans. Herts. N.H.S.*, 1924). It is indeed probable that further research will show that Northern Europe in general has experienced a decrease in humidity. The water of the ponds described by M. Denis is slightly acid (pH 6·0) with only minute traces of Calcium. Sphagneta, as might be expected, are common, and are distinguished by the presence of an Algal association of widespread occurrence in Europe and characterised by the presence of *Micrasterias truncata* and *Frustulia saxonica* (*Vanheurckia rhomboides v. Saxonica*). The successive zones of vegetation from the centre to the margin of these ponds are respectively dominated by *Potamogeton natans* and *P. polygonifolius*; *Glyceria fluitans* and *Juncus supinus*; *Heleocharis palustris*; *Carex rostrata*; and *Molinia cœrulea*. It is of interest to note that *Pilularia globulifera, Elisma ranunculoides, Alopecurus fulvus*, and *Litorella lacustris* are amongst the species regarded as characteristic of the Heleocharetum, whilst a Cicendietum is distinguished in which *Scirpus setaceus, Radiola linoides, Limosella aquatica, Centunculus minimus*, and *Cicendia pusilla* are characteristic.

Knudson, in a recent paper (*Bot. Gaz.*, June 1925) describes experiments on Orchids, grown in organic media from seed, from which he concludes that the fungus is pathogenic, and only important for germination on account of the changes in the environment which it effects, notably by rendering the medium acid and converting organic material into an available form. It is claimed that *Pythium* was as effective in stimulating germination as *Rhizoctonia*.

Cryptogamic.—Under the title " New British Bryophytes " Dixon and Nicholson in the May *Jour. Bot.* record the occurrence of *Grimmia andreœoides*, an alpine moss of Central Europe; *Webera calcarea*; from the Lizard the Dalmatian *Fossombronia loitlesbergeri* and the Mediterranean *Gongylanthus ericetorum*; and *Cephalozia compacta* from Yorkshire. In the same number Watson describes new species of *Stenocybe* and *Clathroporina*, the former from Llanberis, the latter from Gloucestershire and Derbyshire.

In the *Annals of Botany* for April Hanna contributes an interesting paper on sex in *Coprinus lagopus*. The conclusion drawn from the examination of both English and Canadian material is that all strains are heterothallic, as in *Coprinus fimetarius* (Bensande, 1919). Kniep, in 1919, showed that in the heterothallic *Schizophyllum commune*, fruit bodies might be produced from a mycelium derived from a single spore, in which case all the spores of the fruit body are of one sex, and this appears to be true also for *C. lagopus*. Hanna finds that the spores are normally of four kinds, and the paired sexual characters segregate on Mendelian lines. Designating these by AB, *a*B, A*b*, and *ab*, only those mycelia will apparently fuse in which there is no common factor, *i.e.* AB–*ab* or A*b*–*a*B. In the same number Bagchee describes in detail the nuclear changes in the Ascomycetous fungus *Pustularia bolarioides*. In a further contribution on the Entomogenous fungi Petch describes new species belonging to *Cephalosporium* from this country and Ceylon, also species of Gonatorrhodiella, Aschersonia, Eriothyrium, Pyrenochæta, and Muricularia (*Trans. Br. Mycol. Soc.*, May 1925). In the same journal Miss Lorrain Smith gives a résumé of recent work on the Lichens, and A. W. Exell describes the structure of the hymenium of *Stereum purpureum*, *S. hirsutum*, and *S. sanguinolentum*. In each the hymenium consists of branched hyphæ, the terminations of which are regarded as all being potential basidia, and in the last two species thick-walled hyphæ occur in addition, which are unbranched and possibly conductive in function.

Genetics and Cytology.—R. N. Salaman, in the *Journal of Genetics* for July, describes crossing experiments with " mutations " of the dark purple " Arran Victory " Potato, which were characterised by particoloured or almost colourless tubers. Reduction in tuber pigmentation appears to be accompanied by a similar diminution in the pigmentation of the stem and in the number of ovules bearing the character for pigmentation. In the same journal M. B. Crane deals with self-sterility and cross-incompatibility in plums and cherries, from which it appears that some other factor is involved besides the slow growth of the pollen tube.

Tmesipteris tannensis, according to the observations of J. S. Yeates (*Proc. Roy. Soc. B.*, 689) has a maximum number of three nucleoli in the gametophytic nuclei and six in the sporophytic, whilst the diploid number of chromosomes is two hundred. Beer recorded similar numbers in *Equisetum arvense*, where the chromosome number is 115. A table of data is furnished showing that in general high chromosome numbers and several nucleoli are associated, and the view is taken that the nucleoli are products of chromosome metabolism.

Phanerogams.—M. Hacquette, in the *Bull. Soc. Roy. Bot. Belgique* (p. 166, 1925), enumerates some introduced species of Northern France. Amongst these it is worthy of note that *Elodea canadensis*, *Polygonum cuspidatum*, *Claytonia perfoliata*, *Lepidium draba*, *Geranium pyrenaicum*, *Veronica tournfortii*, and *Matricaria suaveolens* are increasing, as is also the case in Britain. Amongst the species which are stated to be decreasing may be noted *Phalaris canariensis*, *Silene gallica*, *Camelina sativa*, *Hyoscyamus niger*, and *Linaria supina*.

In describing thirteen new species of the Rhizophoraceous genus *Cassipourea* in the *Kew Bulletin* (No. 6, 1925), Alston includes the genus *Weihea* of Sprengel and *Dactylopetalum* of Bentham as sub-genera. Members of all the four sections of the genus occur in Western Africa, which would appear to have been its original home, whilst in Central America members of the sub-genus *Cassipourea* have alone been found.

From a study of the past and present distribution of the Magnoliaceæ R. D. O'Good (*Ann. Bot.*, April) agrees with earlier writers in regarding the present distribution as the result of migration enforced by the Pleistocene climate, and the view is adopted that age has played little part in determining their area.

ZOOLOGY. By Reginald James Ludford, Ph.D., B.Sc., University College, London.

The Plankton of the Clyde.—S. M. Marshall has made a survey of the plankton of the Firth of Clyde. Tow-nettings were taken almost every day, over a period of two years. The succession of forms throughout the year is similar to what has been recorded at other British Marine Biological Stations. The spring diatom maximum, however, appears to come earlier, and the summer months July and August are relatively richer in diatoms, compared with Plymouth and Port Erin. The peridinian maximum occurs later on the Clyde than elsewhere. A distinguishing feature of the Clyde winter plankton is the presence of considerable numbers of radiolarians (*Proc. R.S.E.*, 45, 1925).

Metabolism of Dinoflagellates.—Amongst marine plankton the Dinoflagellates are second only to diatoms in abundance, and are of considerable economic importance owing to their serving as sources of food for other organisms. Little is known of their metabolic processes, but the work that has been done on this group has raised many interesting problems. Recently J. R. Bruce has investigated the relationship between the degree of salinity of the sea-water and the process of photosynthesis in *Amphidinium herdmani*, one of the more abundant shore-living Dinoflagellates in the Port Erin area. Experiments showed that the organisms, when suspended in water and exposed to diffuse daylight, were capable of assimilating free carbon dioxide, at all salinities, from that of normal sea-water down to practically fresh water. The rate of assimilation, however, was low when the salinity was outside an optimal range, and Bruce suggests that under these conditions *Amphidinium* may function, facultatively, as a heterotrophic organism. Salinity is also one of the factors in the distribution of this organism, and where it occurred in great profusion the degree of salinity of the water was found to be within the optimum found for carbon assimilation (*Brit. Jour. Expt. Zool.*, **2**, 1925).

The Lipoid Excretion Apparatus of Protozoa.—In the infusorians, *Chilodon* and *Dogielella*, D. Nassonov finds the lipoid excretion apparatus is in the form of a ring, of irregular contour, while in some cases the ring is open. This form of the excretory organ is regarded as more like the Golgi apparatus of the metazoan cell than the cases previously described. Two phases can be recognised during excretion in the protozoan cell, corresponding to stages in secretion in gland cells. Water containing dissolved substances first appears in the form of droplets in the lipoidal substance constituting the ring-like excretory organ, then the small drops flow together and collect in the centre of the ring so as to form a pulsating vacuole, which, except for the surrounding apparatus, lies free in the cytoplasm. The ring-like form of the excretory organ of the protozoa, described in this paper, bears a striking resemblance to the form of the Golgi apparatus in many metazoan cells (*Zeit. für Zellforschung, und Mikr. Anat.*, **2**, 1925).

Paramœcium.—From observations and experiments J. T. Saunders considers that the trichocysts of *Paramœcium* are threads, by means of which it adheres to surfaces. Probably pressure, caused by colliding with an object in the water, causes the extrusion of the trichocysts, which then adhere because their tips are sticky. The rate at which *Paramœcium* moves is dependent upon ciliary activity, and this is influenced by the *p*H of the water, so that, since a sufficient force of compact is necessary for extrusion of the trichocysts to occur, the *p*H of the water is a controlling factor in the functioning of the trichocysts as organs of adhesion (*Proc. Camb. Phil. Soc.*, **1**, 1925).

It has been found by H. M. Fox that light influences the vertical movements of *Paramœcium* and echinoid larvæ, in a similar manner to what has previously been described in the case of Arthropods. Under certain environmental conditions these organisms swim downwards in light, and upwards in darkness. Ultra-violet rays produce the most marked results (*Proc. Camb. Phil. Soc.*, 1, 1925).

Yolk Formation.—The origin of yolk in the egg-cells of the various groups of animals presents interesting variations. During oögenesis in scorpions, according to V. Nath, there are two kinds of yolk formed in some species, and in others only one type. In *Euscorpius napoli* and *Buthus judaicus* nucleolar extrusions occur, and are followed by the appearance of yolk in the cytoplasm. Yolk also arises by the transformation of Golgi bodies. By centrifuging the oöcytes of *Euscorpius* these two kinds of yolk can be completely separated. The yolk of the oöcyte of *Palamnæus* is believed to be derived from the Golgi bodies by a process of fatty degeneration (*Proc. R.S.*, 98, 1925). L. A. Harvey strongly criticises the view that the Golgi bodies give rise to yolk. He studied yolk formation in the ovary of the common earthworm. The so-called yolk-nucleus was found to be a mass of mitochondria. No visible nucleolar extrusions into the cytoplasm were observed, nor was there any direct metamorphosis of either mitochondria, or Golgi bodies into yolk. Harvey considers that the yolk of the *Lumbricus* egg arises from the ground cytoplasm (*Q.J.M.S.*, 69, 1925).

Primitive Form of Mitosis in the turbellarian Stenostomum.—A form of mitosis closely resembling that occurring amongst the Protozoa has been described by C. Stern in epidermal cells of the turbellarian *Stenostomum*. Both the centrosomes and chromosomes appear to arise from the karyosome. The chromosomes become arranged about the equator of the spindle, and divide into the two daughter plates in the typical manner; but the special feature of this mitotic process is that it goes on inside the nuclear membrane. Finally, the nucleus divides into two parts, without any dissolution of its membrane having occurred (*Zeit. für Zellforschung und Mikr. Anat.*, 2, 1925).

The Reproductive Processes of the Earthworm.—Although the earthworm is the subject of universal study on the part of students, reference to the textbooks shows that a considerable difference of opinion exists as to the nature of the reproductive processes in this animal. A. J. Grove has, therefore, reinvestigated this problem, and records direct observations on sexual congress, supplemented by the study of histological sections of earthworm fixed during the reproductive act. Grove's paper also contains an account of the structure of the clitellum, and some notes on the contents of the spermothecæ (*Q.J.M.S.*, 69, 1925).

Bidder's Organ.—K. Ponse has confirmed in a striking manner the view that Bidder's Organ represents an abnormal ovarian structure. After castrating male toads he found that their Bidder's organs assumed the function of ovaries. Further, he succeeded in bringing about sexual congress between such animals and normal males. The fertilised eggs were found to give rise to normal tadpoles (*Compt. Rend.*, **93**, 1925).

Sex and Rejuvenation in Birds.—Sixteen cases of pigeons without a discoverable trace of gonadal tissue have been described by O. Riddle. Despite the absence of testicular tissue some of the birds developed characteristically masculine behaviour. It is believed that such failure of gonad development is a consequence of the failure of all the primordial germ-cells to reach the anlage of the germinal ridge (*Brit. Jour. Expt. Biol.*, **2**, 1925). A further contribution, pointing to the fact that the physiological action of the testis in birds is different from that in mammals, has been made by F. A. E. Crew. This investigator performed unilateral vasoligation in old fowls, and found no indication of rejuvenation such as follows the same operation on mammals. In another series of experiments Crew administered desiccated thyroid to aged fowls of both sexes. Definite rejuvenation effects followed. Cock-feathered cocks, when so treated, assumed a plumage that was distinctively hen-like. It is suggested that " the effect of gonad on plumage is not direct, but that it is secondary to the effect of gonad on thyroid " (*Proc. R.S.E.*, **55**, 1925).

Embryology of the Fowl. (1) *Origin of Germ-cells.*—J. H. Woodger has investigated the origin of germ-cells in the fowl by means of study of the Golgi bodies of chick-embryos. He entertains no doubt about the continuity of the primitive germ-cells of the genital ridge with those of the splanchnic mesoderm of earlier stages. The latter are derived from large cells in the blood-stream of earlier embryos. Such cells seem to arise from the germ-wall endoderm, in front of the primitive streak. There is some cytological difference between the cells in the blood-stream and those of the germ-wall endoderm. Woodger believes, however, that the assimilation of yolk, accompanied by the grouping of the Golgi bodies in the cells of the germ-wall endoderm, would bring about the conditions found in the cells of the blood-stream (*Q.J.M.S.*, **69**, 1925).

(2) *Development of Neurones.*—The scattered reticulate form of the Golgi apparatus is characteristic of neurones. A. Subba Rau and R. J. Ludford find, however, that in the spinal ganglia of the chick of four days' incubation the Golgi apparatus is in the form of a cluster of granules or rodlets, grouped around the centrosphere, at one side of the nucleus. At a certain period, which varies in different neurones, the apparatus hypertrophies and spreads out in the cytoplasm, giving rise to the reticulate form. The medullary cells of the suprarenal

body, which are derived from the central nervous system, have the apparatus in the juxta-nuclear compacted form similar to the cells of the spinal ganglia at the early stages of development (*Q.M.J.S.*, **69**, 1925).

Hypertrophy and Regeneration of the Ovary.—C. G. Hartmann removed one of the ovaries from each of a number of female opossums. This operation was followed by a compensatory hypertrophy of the remaining ovaries, which was found to be due to an increase in the number of Graafian follicles (*Amer. Jour. Anat.*, **35**, 1925). Experiments performed by C. B. Davenport indicate that after complete removal of the ovaries of mice new ovaries may be regenerated. Every precaution was taken to completely remove all traces of the ovaries, yet in nearly two-thirds of the animals experimented upon, ovaries of smaller, or larger size were found after an interval of a few weeks or months. It may be concluded, therefore, that under favourable conditions ovaries "may regenerate *de novo* from the old stalk or even from the peritoneum of the adult mouse" (*Jour. Expt. Zool.*, **42**, 1925).

ENTOMOLOGY. By J. DAVIDSON, D.Sc., Rothamsted Experimental Station, Harpenden.

General Entomology.—J. D. Dobroscky (*Biol. Bull.*, **48**, 274–82) has some general notes on the external parasites of birds and the fauna of birds' nests. R. W. G. Hingston, in a book entitled *Nature at the Desert's Edge* (London: H. F. and G. Witherby, 1925, 299 pp. Price 15*s.* net) deals with the observations made during a summer spent at an oasis in the vicinity of Bagdad: six chapters are devoted to insects and spiders and make very interesting reading. L. O. Howard (*Ann. Entom. Soc. America*, **18**, 1–21) gives a general account of the value of entomology as an applied science. *A General Text Book of Entomology* by A. D. Imms (London: Methuen & Co., Ltd., 1925, 700 pp. and 607 figures, Price 36*s.* net) is an excellent up-to-date work on the subject. A great deal of material which has not hitherto appeared in textbooks is to be to be found in this volume, and the research worker and the teacher will find it a valuable book of reference. A paper, dealing with certain aspects of the applied side of Entomology, is by S. A. Neave (*Empire Cotton Growing Review*, London, 1, No. 3, 191–5) on the work and organisation of the Imperial Bureau of Entomology. A handsome memoir from the Liverpool School of Tropical Medicine entitled, *A Guide to the Study of Tsetse Flies* (Liverpool: The University Press, Ltd., 1925. Price 20*s.* net) by R. Newstead is an important contribution to the bionomics of tsetse flies, being the results of the author's investigations during the past twenty years. C. H. Richardson

(*Dept. Agric. U.S.A.*, 1925, *Bull.*, 1324) deals with the oviposition response of Insects. The desire to feed and to lay eggs are the two chief influences which result in insects being attracted to certain materials. There is a definite precision on the part of many insects as to where the eggs are to be laid. The author discusses the various stimuli which affect the oviposition response.

Orthoptera.—J. H. Bodine (*Biol. Bull.*, **48**, 79–82) ascertained the hydrogen-ion concentration of the blood of seventeen species of grasshoppers by means of appropriate indicators, and found the average *p*H to be 6·8. The same author (*Jour. Exper. Zool.*, **38**, 413–21) has estimated the amount of CO_2 given off by grasshoppers which were placed under the influence of an anæsthetic. Ether produced a marked change in the CO_2 output. It was observed that the respiratory movements were the first signs of the insect recovering from the anæsthetic, followed by those movements controlled or inhibited by the brain, and finally the brain itself. D. Voinov (*Arch. Zool. Exper. et Gen.*, **63**, 437–523) gives a detailed account of the cytology of the sexual elements in *Gryllotalpa vulgaris* Latr., and indicates three different forms of the species, each form having a different chromosome complex. The occurrence of mites in the tracheal system of certain orthoptera is interesting in view of the importance of the acarine disease of the honey-bee, due to *Acarapis woodi*, discovered by Rennie in 1921. L. P. Wehrle (*Ann. Entom. Soc. America*, **18**, 35–44) discusses the presence of a tarsonemid mite *Locustacarus trachealis* Ewing (1924), which inhabits normally the tracheal system of the adult females of two species of grasshoppers. The mites occur in the principal tracheæ and air-sacs of the head and body and infestation may be slight or severe, but the method of infestation is unknown. It is suggested the mites may enter through the large thoracic or abdominal spiracles. All stages of the mite may be found in the same host.

Coleoptera.—A further volume on *The Fauna of British India, Coleoptera* by P. J. Arrow (London: Taylor and Francis, 1925, 416 pp.) deals with 354 species belonging to the *Erotylidæ*, *Languriidæ*, and *Endomychidæ*. J. K. Breitenbecker (*Biol. Bull.*, **48**, 166–70) describes an apterous mutation in *Bruchus*. A study of the movements of larvæ of the Limacodidæ has been made by W. J. Crozier (*Jour. Exper. Zool.*, **38**, 323–9): these larvæ have curious creeping movements and in four genera studied, prolegs were found to be absent and the thoracic legs much reduced; they creep by means of waves of muscular activity, which resemble those seen on the pedal surface of chitons and gastropods. W. S. Fisher (*Proc. U.S.A. Nat. Mus.*, 65, Art. 9, 1–207), in a revision of the West Indian Buprestidæ, deals with 29 genera and 107 species. Interesting notes on the leaf-mining habits of certain beetles are given by S. W. Frost (*Ann. Entom. Soc. Amer.*, **17**, 457–67), a synopsis of the leaf-mining Coleoptera of the world, and the host plants which they mine being included. C. C. Hamilton (*Proc. U.S.A. Nat. Mus.*, **65**, Art. 17, 1–87) has a paper on the morphology, taxonomy and ecology of the larvæ of the holarctic Cicindelidæ. In continuation of previous work published in 1911, R. Jeannel (*Arch. Zool. Exper. et Générale*, **63**, 1–436, 498 figs.) has an important monograph on the Bathysciinæ group of the Silphidæ; the members of this group are located chiefly in southern and eastern Europe, and there is only one British representative, *Adelops woollastoni* Janson, which is here placed in the genus *Parabathyscia*. R. Kleine (*Indian Forest Records, Entom. Ser.*, **11**, Pt. 1, 1–48) deals with the Brenthidæ, which is an important group in relation to forest trees in India; several new forms from India are described and a synoptic key to the genera is given. In the same publication (Pt. 2, 1–18) C. F. C. Beeson gives some biological notes on the family.

The value of the aeroplane as a means of applying insect poisons over large areas, which first came to the notice of the public in 1921, is now definitely established in America as a commercial success, and G. B. Post (*Georgia State Coll. Agric. Bull.*, 301) gives an account of the use of the aeroplane in the control of the boll-weevil of cotton. W. Schultze (*Philippine Jour. Science*, **26**, 131–309) in part 3 of his studies on the Pachyrrhynchid group of the Curculionidæ, deals with the genera *Apocyrtidius* Heller and *Metapocyrtus* Heller.

Lepidoptera.—J. H. Gerould (*Genetics*, **8**, 495–551) has a paper on the inheritance of the white wing colour in the Pierid butterflies *Colias philodice* and *C. eurytheme*; there are two types of females in these species, one type having yellow wings, resembling the male, and another type with white wings; the former is recessive to the white-winged form, being differentiated by a single pair of factors; the white wing colour appears to be a sex-controlled character (Goldschmidt), its appearance being inhibited by the development of the male characters; it is latent in the male and revealed in the female. L. B. Ripley (*Illinois Biol. Monographs*, **8**, No. 4) gives an account of the external morphology and post-embryology of Noctuid larvæ. A detailed account of *Tortrix pronubana* Hb., especially with reference to the larval and pupal stages, is given by R. C. Fisher (*Ann. Appl. Biol.* **11**, 395–447); this moth has been found in large numbers on plants in glasshouses at Kew Gardens; two generations occur in the year, the summer one emerging from the eggs laid in spring, and a winter one emerging from eggs laid in autumn.

Owing to the heavy infestation of spruce forests in Bohemia by the nun moth, J. Komarek and V. Breindl (*Zeitschr. angew. Entom. Berlin*, **10**, No. 1, 99–162) have made a study of the polyhedral disease of this moth, with a view to seeing whether it can be used as a method of control against its destructive caterpillars: the causal agent of the disease resembles the micro-organisms called *chlamydozoa* by Prowazek, the polyhedral bodies being the final stage in the cycle of these organisms: infected caterpillars die and decompose, setting free the polyhedral bodies, which are deposited on leaves, etc., and are then taken into the stomach by the caterpillars feeding on the leaves: the intestinal cells are not affected and therefore do not form polyhedral bodies, so that the excreta is not normally infective. The second part of the catalogue of type specimens of Lepidoptera Rhopalocera in the British Museum, by N. D. Riley and A. G. Gabriel, deals with the Danaidæ, 1,200 species being listed, together with type localities. Some interesting observations on the early larval activities of the aquatic *Nymphula maculalis* Clemens are given in a paper by P. S. Welch (*Ann. Entom. Soc. America*, **17**, 395–402); the larvæ, hatching from egg masses laid on the lower surface of floating leaves of the yellow water-lily, sink to the bottom and feed on the tender submerged leaves: during practically the period of the first two larval instars, the insect remains at the bottom, but after that it migrates to the surface, where it spends the remainder of its larval life.

Hemiptera.—The mouth parts and mechanism of suction in Hemiptera have received attention from several workers of recent years, and a paper by F. Brocher (*Ann. Soc. Entom. de France*, **94**, 55–66), contains an anatomical and physiological study of the mouth parts of the early stages of *Psylla pyrisuga* Fstr. An important monograph by W. L. MacAtee and J. R. Malloch (*Proc. U.S. Nat. Mus.*, **67**, Art. 1, 1–153), deals with a revision of the sub.-fam. Ploiariinæ (Reduviidæ). H. Morrison (*Jour. Agric. Res.*, **30**, 97–154) gives an account of the scale insects of the sub.-fam. Ortheziinæ: this group has a wide distribution, and includes several species, which are injurious pests; many of the forms are interesting on account of their beautiful superficial appearance, due to the plate-like tufts of waxy secretion. In 1902 Wassman erected the genus *Termitaphis* for an insect which was thought to be an aberrant aphid; later, eight other allied species were discovered, and J. G. Myers (*Psyche*, **31**, 259–78) now describes a new genus, *Termitaradus*, from Panama: the systematic position of the family is discussed, a new family name, *Termitaphididæ*, being given.

J. Szabó-Patay (*Ann. Musei Nationalis Hungarici*, Budapest, 1924, **21**) describes the structure and function of the respiratory apparatus of *Aphelochirus*: it appears that this water-bug does not come to the surface to breathe, being able to extract oxygen from the air dissolved in the water, by a peculiar arrangement of the tracheal system and its attendant structures; the observations, however, await confirmation as only dried material has so far been examined.

Hymenoptera.—The Braconidæ is a family of great interest on account of the habits of its members as parasites of other insects, and C. F. W. Muesebeck (*Proc. U.S. Nat. Mus.*, **67**, Art. 8, 1–85) gives a revision of the genus *Microbracon* in North America. Another important monograph by H. L. Parker (*Ann. Soc. Entom. de France*, **93**, 261–392, 39 pls.) deals with the (larvæ) post-embryonic forms of members of the vast family the Chalcididæ; these studies, which form a review of the anatomy and morphology of the larvæ of all the known chalcids, have been carried out during the past few years at the parasite Laboratory of the U.S.A. Bureau of Entomology at Hyères in the South of France, and form a valuable contribution to our knowledge of this important family. J. A. Nelson (*Jour. Agric. Res.*, **28**, 1167–1213) has a detailed study of the morphology of the larva of the honey-bee. Another valuable publication on the honey-bee is by R. E. Snodgrass, entitled, *The Anatomy and Physiology of the Honey-bee* (McGraw-Hill Publishing Co. Ltd., London, 1925, 327 pp.) a review of which appears in this number of SCIENCE PROGRESS.

The British species of *Megachile* are dealt with by R. C. L. Perkins (*Entom. Mo. Mag.*, **61**, 95–101) descriptions of some new varieties from Ireland being given.

F. Santschi (*Revue Suisse Zool.*, **31**, 157–73) has given a useful revision of the African genus *Plectroctena* of Ponerine ants. Little is known of the habits of these ants, which live in chambers, deeply situated in the ground, the entrance to the nest being usually indicated by a mound of earth: they are sluggish, timid insects, about fifty members in a colony; exploration is confined to the workers, and their food includes termites, but chiefly millepedes and certain beetles.

Diptera.—G. C. Crampton (*Proc. Ent. Soc. Washington*, **27**, 68–90) discusses the phylogenetic significance of the labium of holometabolous insects, with special reference to the Diptera, which paper is in the form of a reply to the criticisms of MacGillivray on Crampton's previous views: the author concludes that the main evidence of the labium is in accord with that afforded by other parts of the body in indicating the relationships of the Holometabola, as shown in previous papers; the evidence points to an Orthopteroid ancestry for the Holometabola, which is probably found in the common Protorthopteran stem, from which such forms as the zorapterous psocids are also derived. Another paper by the same author (*Ann. Entom. Soc. America*, **18**, 49–74) deals with a phylogenetic study of the thoracic sclerites of the non-Tipuloid Nematocera: the view is held that the families Tanyderidæ, Bruchomyidæ, and Trichoceridæ are among the most primitive living Diptera. Further remarks on this question by the same author appear in (*Psyche*, **31**, 238–42).

C. H. Curran (*Proc. Entom. Soc. Washington*, **27**, 51–62) has a revision of the Syrphid genus *Neoascia* Williston, six new species being described and M. C. van Duzee (*Proc. U.S. Nat. Mus.*, **66**, 1–43) has revised the N. American species of the Dolichopodid genus *Argyra* Macquart, 26 new species being described. L. Faleoz (*Arch. Zool. Exper.*, **61**, 521) describes 11 species of Pupipera from caves, being chiefly parasitic on bats: the species evidently associate with different species of bats, and certain species are free-living during part of their life, for instance *Penicillida dufouri* places its young, not on the host bat, but on the wall of the cave or on a branch from which the young insect seeks its host: two species new to science are described, *Nycteribia scotti* and *Nycteribosca alluandi*. Q. C. Kessel (*Jour. New York Entom. Soc.*, **33**, 11–33) has a synopsis of the family Streblidæ, also parasitic on bats. C. T. Greene (*Proc. U.S. Nat. Mus.*, **66**, 1–26) gives an account of the puparia and larvæ of Sarcophagid flies. The addition of 13 new species of Diptera to the fauna of the Galapagos Islands by C. W. Johnson (*Zoologica*, **5**, 85–92) brings the total records of Diptera from these islands up to 50 species. Experiments on the phototropic reactions of *Eristralis tenax* and *Erax rufibarbis* have been carried out by S. O. Mast (*Jour. Exper. Zool.*, **38**, 109–205). These flies are photopositive, and, when illuminated laterally, they turn directly towards the source of light; when illuminated from two sources they take up a line between the two, the position depending upon the relative intensity of the light from each source: removal of the limbs shows that orientation does not depend necessarily on balanced action in the locomotor appendages of opposite sides, as suggested by the "Ray-Verworn" theory; it is produced by a series of co-ordinated reflexes, specifically related to the photo stimulation of the eye, and any hypothesis which demands balanced action in receptors and locomotor appendages on opposite sides, does not fully explain orientation in insects.

M. H. Morris (*Bull. Entom. Res.*, **15**, 359–60) records the finding of the eggs of *Leptohylemyia coarctata* Fall in the soil of a mangold-field, thus confirming previous observations that this phytophagous insect has the unusual habit of laying its eggs in the bare soil in the absence of its host plant: a description of the egg is given. A further volume in the *Faune de*

France series (Paris, 1924, P. Lechevalier, pp. 1–159) is an important monograph on the Tipulidæ by C. Pierre, and a valuable treatise on the mosquitoes of the Mediterranean area is written by E. Séguy, *Les Moustiques de l'Afrique mineure, de l'Égypt et de la Syrie* (Paris, 1924, P. Lechevalier, 257 pp., 29 pls., 106 figs. Price 50 frs.). E. Smirnov (*Zool. Anz.*, **58**, 349–50) shows that the internal anatomy of *Cerioides*, which, on account of its curious external appearance, is considered to form a special sub-family, is also unusual in Diptera ; a new species, *C. sartorum*, from Turkestan is described. J. Surcouf and E. Fischer (*Bull. Soc. Entom. de France*, 1924, No. 20, 232–7) have some interesting notes on the larval and nymphal life of *Tabanus bromus* L., and A. Thienemann (*Zool. Anz.*, **58**, 331–45) deals with the larval and pupal stages of some Chironomidæ, particularly the genus *Lundströmia* ; the forms in different groups appear to be quite similar, and it is necessary to breed out the imago before the classification can be certain. C. L. Turner (*Biol. Bull.*, **48**, 128–38) describes a mutation which arose during breeding experiments with *Psychoda alternata*.

Other Orders.—Certain questions with relation to the intestinal protozoa and digestion in termites is the subject of three papers by L. R. Cleveland (*Biol. Bull.*, **48**, 282–8 ; 289–93 ; 295–327). The protozoa in the distended gut of the host take into their bodies, and digest, practically all the wood which the termites eat, and the latter cannot live on wood, their normal food, in the absence of these protozoa ; the author shows how the protozoa *Trichonympha campanula* digests the wood. It is also shown by experiment that *Termopsis* sp. and *Reticulitermes* sp. can live on a diet of pure cellulose, it having been hitherto thought that a diet of cellulose was insufficient to maintain normal development ; it is suggested that the insect must be able, therefore, either to fix atmospheric nitrogen or transform carbohydrates into proteins. D. M. Diakinov (*Jour. Genetics*, **15**, 210–32) has made an experimental and biometrical study on the dimorphic variability of *Forficula*, particularly with reference to the forceps in the male. Although the length of the forceps in the male may sometimes vary widely, they may present a typical bimodal frequency curve ; the writer considers that the cause of the dimorphism is only a specific and rather complex reaction-norm, where a modification, under the ordinary conditions, proceeds very rapidly.

B. B. Fulton (*Ann. Entom. Soc. America*, **17**, 357–67) has some interesting observations on the habits of earwigs, the forceps being considered chiefly as organs of defence. In (*Zoölogica*, **5**, 67–76 ; 77–9 ; 81–4) J. W. Folsom describes two new Apterygota, H. Osborn describes *Jassus galapagensis* n.sp., and H. E. Ewing describes new species of Mallophaga ;

all from the Galapagos Islands. Several new genera and species of Thysanoptera collected by C. B. Williams in Central America are described by H. J. Douglas (*Psyche*, **32**, 48–69) and seven new species from Africa (*The Entomologist*, **58**, 132–9; *Proc. Entom. Soc.*, Washington, **27**, 8–12).

PHYSIOLOGY OF REPRODUCTION. By John Hammond, M.A., School of Agriculture, Cambridge.

Rejuvenation and the Internal Secretions of the Testes.—The attempt to ward off the senile decay of old age has attracted many investigators, and lately the vigour imparted to the organism by the internal secretions of the testes have formed the basis of new attempts in this direction. Steinach (*Arch. f. Entwick. Mech.*, **46**, 1920) has used the method of vasectomy, or ligature of the epididymis to increase the internal secretion of interstitial tissue at the expense of the external secreting seminiferous tissue, as had previously been found by Ancel and Bouin (*Arch. de Zool. Expér.* **1**, 1903). His claims have received confirmation recently in the publications of Sand (*Zt. Sexualwiss.*, **8**, p. 3, 1922) and of Schmidt (*The Theory and Practice of the Steinach Operation*, London, 1924). On the other hand, Voronoff (*Greffe Animale, ses applications utilitaires au Cheptel*, 2nd edit., Paris, 1925), by the transplantation of the testes of young animals into senile ones, has obtained remarkable rejuvenating effects in the larger domestic animals and in man; in conjunction with Retterer (XI. Inter. Phys. Congress, Edinbugh, 1923; *Supp. Quart. Jour. Exp. Phys.*), he is inclined to believe that the result is due to the introduction of the elements of the seminiferous tubules rather than to the interstitial tissue. In cocks, where the interstitial tissue is very scanty, Crew (*Proc. Roy. Soc. Edin.*, **45**, p. 249, 1925) failed to obtain any rejuvenating effect from vasectomy, although he states (*Proc. Roy. Soc. Edin.*, **45**, p. 252, 1925) that a positive result was obtained by the administration of thyroid.

The literature of the controversy as to the origin of the internal secretions of the testes has been summarised in a new edition of Lipschütz's book, which has been published in English (*The Internal Secretions of the Sex Glands*, Cambridge, 1924). In this connection the secondary sexual characters of fishes have provided interesting evidence. It was known from the work of Kopeč (*C. R. Soc. des Sci. de Varsovie*, **11**, 1918) that the sex-glands influence the secondary sexual characters. Courrier (*Archiv. d'Anat. d'Hist. et d'Embry.*, **2**, p. 118, 1922), from an examination of the seasonal changes in the secondary sexual characters in conjunction with the changes in the proportions of seminiferous and interstitial tissue in the testes, concluded that the interstitial tissue is the origin of the internal secretions; but Van Oordt (*Konink. Akad. v. Wetensch. te Amsterdam*, **26**, 1923, and **27**, 1924, and *Arch. f. Mik. Anat. v. Entwickmech.* **102**, p. 379, 1924) finds that the evidence does not support this conclusion, and suggests that the difference in the proportions of these tissues present is the result of alternating action of interstitial and seminiferous portions dependent on the supply of nutritive substances to the testes.

Secondary Sexual Characters and Mendelian Factors.—Geneticists are at present inclined to favour the sex chromosome theory as the basis for the inheritance of sex, and this implies differences in the soma of males and females. Lipschütz, in his book (see above), and in a recent paper (*Mendel Memorial Pub. Czechoslovac Eugenics Soc.*, Prague, 1925) points out that this conflicts with the views of physiologists such as Tandler (*Arch. f. Ent. Mech.*, **31**, 1910), Steinach (*Pflügers's Archiv*, **144**, 1912), and Zawadowsky (*Das Geschleckt und die Entwicklung der Geschlechtsmerkmale*, Moscow, 1922) and others who, from the effects of castration or artificial hermaphroditism, or transplantation of gonads, are inclined to view the soma as asexual or bisexual, for the soma of both sexes reacts in the same way to the internal secretions of either sex. Lipschütz suggests that a physiological study of sex-linked crosses by castration and transplantation of gonads will assist both geneticist and physiologist in solving these problems.

Œstrus and the Œstrous Cycle.—The causes of the changes in the reproductive organs and the occurrence of the desire for coitus during the heat periods of an animal have been the subject of recent work by Allen, Doisy, *et al.* (*Amer. Jour. Anat.*, **34**, p. 133, 1924), who state that they have been able to obtain the active principle causing these changes from the Graafian follicle by chemical extraction, and that small doses of such substances, which are not species specific, injected into sprayed females will cause all the symptoms of heat, and that females so treated will accept coitus; it was not possible to extract such a substance from the *corpus luteum*. Similar results have also been obtained by Courrier (*Arch. de Biol.*, **34**, p. 370, 1924).

Loeb (*Biol. Bull.*, **27**, p. 1, 1914) found that the early extirpation of the *corpora lutea* in guinea-pigs led in most cases to an earlier ovulation than usual, and it has been found (Hammond, XI Inter. Phys. Cong. Edinburgh, 1923; *Supp. Q. J. Exp. Phys.*, p. 133) that the length of the œstrous cycle in cows can be reduced by squeezing out the *corpus luteum* from the ovaries *per* rectum; heat occurs again two days after the operation, and this is followed by another ovulation. It would appear, therefore, that it is the length of life of the *corpus* *luteum* which determines the length of the œstrous cycle in so far as it regulates the ripening of the Graafian follicles. In the rabbit (Hammond and Marshall, XI Inter. Phys. Cong., Edinburgh, 1923; *Supp. Q. J. Exp. Phys.*) there is absence of a regular œstrous cycle, and this is associated with the fact that it does not ovulate unless coitus occurs; in the absence of copulation rabbits remain on heat for long periods when conditions for the ripening of the Graafian follicles are suitable. In this species pseudopregnancy, which ensues after a sterile mating, takes the place of an œstrous cycle.

On the whole, the *corpus luteum* is remarkably regular in its duration during the cycle, but certain conditions, such as pregnancy, cause it to persist much longer before the atrophic changes occur; it is, therefore, a somewhat unexpected result that has recently been obtained by Loeb (*Proc. Soc. Exp. Biol. and Med.*, May 1923), who finds that in guinea-pigs removal of the uterus causes the *corpus luteum* to persist much longer than in the normal cycle. Hartman (*Amer. Jour. Anat.*, **35**, p. 25, 1925) has, however, failed to obtain similar results in the opossum.

The details of the œstrous cycle vary so much from species to species that it is dangerous to homologise apparently comparable processes in different species unless the full details of the cycle have been worked out. The cause of the menstrual flow in women, which has sometimes been regarded as due to the influence of the follicle (a pro-œstrous effect, similar to that which occurs in the bitch), may also be explained as a premature abortion or breakdown of the mucosa owing to the ovum not being fertilised and the placenta not being formed. Corner (*Contributions to Embryology*, No. 75) has recently attempted to solve this and related problems in monkeys. He found ovulation to occur fourteen to fifteen days after the onset of the last menstruation and an indication of a probable correlation between the premenstrual period in the primates and the post-œstrous period of other animals; in some individuals, however, which had menstruated within two weeks of killing, he found no signs of recent or impending ovulation; this may possibly be associated with the difficulties of keeping these animals in captivity out of their native country. It has been established by the work of Fraenkel, Meyer, Ruge, and Schröder that ovulation in women occurs ten to fourteen days after the beginning of the menstrual flow. Seitz and Wintz (*Münchener Med. Wochensch.*, p. 475, 1919) find that the effect of Röntgen rays, which destroys the follicular system of the ovary, varies according to the time in the cycle at which it is administered; if given in the first half of the intermenstrual period (*i.e.* before a new *corpus luteum* has been formed) no further menstrual flow occurs in the majority of cases, whereas if administered in the second half (*i.e.* after ovulation when a fresh *corpus luteum* exists in the ovary) one more menstrual flow takes place in the majority of cases before complete cessation ensues. This appears to indicate that the atrophy of the *corpus luteum* rather than the ripening of the follicle is associated with the onset of the menstrual flow. The method of implantation of the human ovum—one of active burrowing into the endometrum—and its early development has been described by Teacher (*Jour. of Obstetrics and Gynæcology of the British Empire*, **31**, p. 166, 1924, and *Zeit. f. Anat. v. Entwick.*, **76**, p. 360, 1925).

Ovarian Metabolism.—The compensatory hypertrophy of one ovary or part of an ovary when the other is removed, a fact determined by earlier investigators, has lately been the subject of experiments by several workers. Arai (*Amer. Jour. of Anat.* **28**, p. 59, 1920) found that the hypertrophy was due primarily to increased follicular development and Asdel (*Brit. Jour. of Exp. Biol.* **1**, p. 473, 1924) has shown in the rabbit that the number of follicles ripened and young produced is practically the same whether the animal has two or only ⅛th of an ovary. Hartman (*Amer. Jour. Anat.*, **35**, p. 1, 1925) goes even further, and states that in the opossum more follicles are produced from a part than from the whole ovarian mass. Lipschütz (*Brit. Jour. Exp. Biol.*, **2**, p. 331, 1925) has shown that the increased development of follicles in fragments of the ovary is not due to the formation of new ova, and that exhaustion of ova may be produced in these fragments due to the numbers which are forced to develop. As he points out, the hypertrophy of fragments of the sex-glands is not due to a demand for their internal secretions, as small pieces are sufficient for this purpose. It seems more probable that the development of the follicles and of the sex-glands generally depends on specific substances which are present in the blood in definite small amounts (Sand, *Jour. d. Phys. et de Path. Génér.* **20**, p. 422, 1922 ; and Hammond and Marshall, XI Inter. Phys. Congress, Edinburgh, 1923 ; *Supp. Q. J. Exp. Phys.* **1**, 137), and the supply of which controls the number of follicles which can develop.

Further evidence for the dependence of the ovary on these specific substances for its internal secretory function and for its function of producing ripe follicles and *corpora lutea* is to be found in the investigations of the effects of lactation on fertility.

Kuramitsu and Loeb (*Amer. Jour. of Physiol.*, **56**, p. 422, 1921), who investigated the effect of suckling on the uterus of the guinea-pig and rat in which a hyperinvolution occurs, conclude, however, that it is not a mediate one acting through the ovaries, and they base this on the fact that there is a slight effect due to suckling on the uteri of castrated animals. Loeb and Kuramitsu (*Amer. Jour. of Physiol.*, **55**, p. 443, 1921) found in the rat that ovulation was suspended during lactation. In rabbits Hammond and Marshall (XI Inter. Phys. Congress Edinburgh, 1923 ; *Supp. Q. J. Exp. Phys.*, p. 137) found that suckling causes atrophy of the uterus very similar to that which occurs as a result of removing the ovaries, and that the effect on the ovaries is to cause atrophy of the follicles and shrivelling of the *corpora lutea*; this is believed to be due to the use by the active mammary gland of the specific substances from the blood which are necessary for the metabolism of the ovary, so that a functional castration is performed with reduction of the internal secretions, although the ovary itself is intact and will function again as soon as lactation ceases or is reduced. That the gonads are particularly susceptible to deficiencies of Vitamine B and other specific substances in the diet has been shown by the work of Evans and Bishop (*Jour. Metabolic Research*, **3**, 1923), and of Parkes and Drummond (*Proc. Roy. Soc. B.* **98**, p. 147, 1925), and it is possible that these facts are connected with those mentioned above. Nichols (*Jour. of the Ministry of Agriculture*, **31**, Dec. 1924) has summarised the existing and has brought forward fresh evidence to show that flushing (raising the state of nutrition) before mating increases the fertility of sheep. Some substance existing in only limited amounts in the blood (" generative ferment ") has also been postulated as a basis for the œstrous cycle (see above), *corpora lutea* and follicles using it alternately (Hammond, XI Inter. Phys. Cong., Edinburgh, 1923 ; *Supp. Q. J. Exp. Phys.*, p. 133), and it may also similarly explain the cycle of changes occurring in the testes of fishes (see above).

Duration of Pregnancy and the Cause of Parturition.—While many theories exist on these points but little experimental evidence is yet available in support of any of them. Kirkham (*Anat. Rec.*, **11**, p. 31, 1916–17), and others have found that lactation prolongs the duration of gestation in mice and rats and this is attributed to the delay in the fixation of the blastocysts to the uterus as a result of lactation. As to the causes of parturition Dixon and Marshall (*Jour. Phys.*, **59**, p. 276, 1924), as a result of experiments, suggest that the internal secretions of the ovary at term stimulates the pituitary and that its secretions in turn act on the muscle of the uterus, causing expulsion of the fœtus. Extracts of ovaries and *corpora lutea* during mid-pregnancy, they found, had no such action on the pituitary.

EDUCATION. By A. E. Heath, M.A., University, Liverpool.

In each field of human endeavour there are periods when advance is made through the perfecting of methods and instruments. There are other periods in which progress is achieved not so much by technical improvements as by a change of attitude to the whole domain. In education, the twentieth century has been marked so far by developments of the first kind; but there seems to be evidence that fundamental changes may arise in the next decade from a real shift in our point of view of education as a whole. Prophecy is a tricksy game, and not to be undertaken lightly in a post-war world bristling with problems; but two recent publications have brought to clearer focus in my own mind the sense of these possibilities.

The first of these is the reissue of Mr. George Sampson's stirring little book *English for the English* (Cambridge Press, 1922; new edition at 2*s.* 6*d.*, 1925). When I first picked up this volume I expected to find a plea for the importance of thorough grounding in the mother-tongue, and a body of practical suggestions as to how that might be achieved in English schools. These expectations were not disappointed. But what I did not think to find was so plain and outspoken and humorous a treatment of English education as a whole, and so broadly built and noble an appeal on behalf of the great mass of English children. We all knew, before Mr. Sampson told us, that the English child can only awaken to any creative fullness of life if he can first become proficient in the use of his native tongue, the universal tool of all callings and of all conditions. But it had not been brought home to us by such vivid phrases as these: " English is not a school ' subject ' at all. It is a condition of school life. . . . Every teacher is a teacher of English because every teacher is a teacher in English." It is, however, the manner in which these questions are related to social and political issues that gives to Mr. Sampson's work its true importance. It provides an indication, as I have hinted above, of a movement of opinion towards the recognition that particular difficulties can only be hopefully treated when they have been placed in a wider setting. Mr. Sampson's attitude to the problem of the 'penny dreadful' will illustrate what I mean. After referring to the agitated nonsense often talked on this subject as a consequence of that " false austerity whose truer name is humbug," he warns us that a year's reading of the average boy is probably much healthier than a year's reading of his critics. The effect of the weekly ' dreadful ' on the mind of the boy is much less harmful than the effect of the daily newspaper on the mind of the adult. The average newspaper, he insists, is deliberately pernicious in suggestion and in suppression. There is too often clear evidence that one of its main purposes is "to perpetuate animosity, produce misunderstanding, alienate sympathy and create the atmosphere in which disputes can never be adjusted, troubles avoided, or wrongs righted." What we have to do, then, is firstly to take the boy's passion for reading, and enlarge its range. But Mr. Sampson is quite clear that this in itself is not enough. "We want to create people who can use print, not people who are intimidated by print." He therefore claims that the proper treatment of this question in schools will point the way towards the solution of the problems raised by uncritical acceptance of printed suggestions in later life. To that end he proposes that the boy of fourteen should be introduced to a kind of reading that finds no place in the usual scheme. "I want him to make a first acquaintance with philosophy," he says, "and, to put the matter in a simple and concrete way, I will suggest that he should begin to read Plato." He begs us to glance through the *Crito* and ask ourselves, first, what there is in it that a Seventh Standard or Fourth Form boy cannot follow; and next, whether that process of steady mental interrogation, that gradual reduction of abstractions either to thin air or to something actual, is not precisely the kind of education our pupils need and ought to get. The shock of such a proposal brings home to us the following facts: (1) that the elementary schools are by far the most important schools in the country, since they are the chief means of humanising the great mass of people; and (2) that these schools have arisen as the product of historical circumstances whose determining factors have too often been commercialism, drift, and snobbery. "One of the gravest social errors of the last half century has been the deliberate depreciation of the real public schools of England, the elementary schools." The matter, as Mr. Sampson points out, may be put quite simply: "Harrow is allowed to make men; Hoxton has to make hands." And all this in spite of the fact that the safety of the world and the future of civilisation depend upon the character and intelligence of the multitude. The point I am making is that when an honest observer like Mr. Sampson comes to treat a single special difficulty in schooling, he is bound to find that its unravelling places threads in his hand leading to almost every department of social organisation. That is what I mean by saying that this book illustrates a change in the treatment of educational questions; and that advance may come in the future from shifts of emphasis in men's thought on these matters, rather than from the polishing of existing methods and machinery.

The other recent publication which seems to me to be a sign of this current in educational affairs is Prof. J. J. Findlay's book, in two volumes, *The Foundations of Education : A Survey of Principles and Projects.* The first volume only (*Aims and Organisation*, Univ. of London Press, 1925) has appeared so far. The distinguishing character of this work is its explicit recognition of the fact that any living survey of educational theory must be related to principles of organisation which, in turn, are the product of social and political changes. " It was only after wide reading in sociology," Prof. Findlay writes, " that the ground seemed to be firm under my feet." There are many instances in this work of the fact that new lines of advance may come from deep-seated movements in opinion : and Prof. Findlay's treatment provides us with ample warning that such advances would not render unnecessary the detailed development of technique. On the contrary, gains on this wider front need to be consolidated by that perfecting of methods and instruments to which it is the complement.

The following is a selection of references to recent work :

JOHN B. WATSON, " The Unverbalized in Human Behaviour," *Psy. Review*, 1924, **31**, 4, 273–80. Stress is laid on the formation of enormous numbers of manual habits, especially during infancy, without corresponding verbal habits. This is made the basis for the curious " behaviourist " view that memory is the calling out of verbal parallels to earlier manual habits. See also the same author's article, " The Place of Kinæsthetic, Visceral and Laryngeal Organisation in Thinking," *Psy. Review*, 1924, **31**, 5, 339–47.

C. S. MYERS, " Some Present Tendencies of Psychology," *Amer. Jour. of Psy.*, 1925, **36**, 1, 53–65.

ALBERT P. WEISS, " Purposive Striving as a Fundamental Category of Psychology," *Psy. Review*, 1925, **32**, 1, 171–7. A criticism of McDougall's address to the Psychology Section of the British Association at Toronto (reprinted in *Scientific Monthly*, 1924, **19**, 305–12).

W. H. R. RIVERS, " Psychological Dissociation as a Biological Process," *Scientia*, 1924, **35**, 145, 331–8. A paper by the late Dr. Rivers which is of interest to readers of his book *Instinct and the Unconscious.*

C. SPEARMAN, " The New Psychology of ' Shape,' " *Brit. Jour. of Psy.*, 1925, **15**, 3, 211–25. A critical account of *Gestalt* psychology. See also J. R. KANTOR, " The Significance of the Gestalt Conception in Psychology," *Jour. of Philosophy*, 1925, **22**, 9, 234–41 ; H. HELSON, " The Psychology of Gestalt," *Amer. Jour. of Psy.*, 1925, **36**, 3, 342–70 ; and OLIVE B. GILCHRIST, " A New View of Mental Development," *Psy. Review*, 1924, **31**, 4, 297–310. Two recent books which are important in this connection are *The Growth of the Mind*, by K. Koffka, and *The Mentality of Apes*, by W. Köhler. An interesting, but not very substantial, parallel is drawn between Gestalt-Psychology and Physical Relativity by G. HUMPHREY, " The Theory of Einstein and the Gestalt-Psychologie," *Amer. Journ. of Psy.*, 1924, **35**, 3, 353–9.

A. E. CHAPMAN, " The Effect of School Training and Special Coaching on Intelligence Tests," *Forum*, 1924, **2**, 3, 172–83. The aim of intelligence tests is " to devise a means of gauging a child's inborn mental capacity." The result of this enquiry is to suggest that environmental factors are more important than is commonly supposed. Further investigation on these lines is clearly much to be desired.

R. L. Archer, "Cross-Currents in the Teaching of History," *Forum*, 1924, **2**, 3, 165–71. So much humbug has been talked and written on the teaching of history that this stimulating and vigorous essay is most welcome. A strong plea for widening the basis of historical studies—especially in adult classes—is put forward by R. S. Lambert, "Anthropology and the Social Sciences," *Highway*, 1925, **17**, 3, 117–22.

T. P. Nunn, "An Elementary School Syllabus in Mathematics," *Forum*, 1924, **2**, 3, 204–19; and 1925, **3**, 1, 49–61. The publication of this exceedingly interesting course will be of the greatest value to many teachers. F. Cajori, "Indivisibles and 'Ghosts of Departed Quantities' in the History of Mathematics," *Scientia*, 1925, **37**, 157. E. J. G. Bradford, "Suggestion, Reasoning, and Arithmetic," *Forum*, 1925, **3**, 1, 3–12. By the systematic setting, in arithmetic papers, of questions not capable of numerical treatment, a remarkable absence of critical thought in answering such papers was disclosed. Teachers of arithmetic would find checks of this kind of great utility in testing the value of their work and methods.

T. H. Yorke Trotter, "Music as it is Taught," *New Ideals Quarterly*, 1925, **1**, 2, 26–30. An important criticism of present tendencies in musical education.

Sir Berkeley Moynihan, "The Debt that Science owes to Medicine," *School Sci. Rev.*, 1924, **6**, 23, 145–59. In this stimulating presidential address to the Science Masters' Association, the subject is treated in a non-technical manner, stress being laid on science as a developing whole. There are several recent papers of interest to the teacher of science from this point of view; Lawrence K. Frank, "The Development of Science," *Jour. of Philosophy*, 1924, **21**, 1, 5–28, suggests that the enduring work of philosophy has been the efforts, not to reveal nature's secrets, but rather to strike off man's fetters and disclose his self-generated obstacles to learning from events; Vivian T. Saunders, *School Sci. Rev.*, 1925, **6**, 24, 217–22, discusses the muddled notions which are current concerning the true function and character of scientific theories, and their relation to facts. The view is expressed that, in our eagerness to encourage some appreciation of scientific work as a living growth, we may rush from the extreme of uninspired technicalities to that of unsubstantial romancing.

H. Crichton Miller, "The Adult's Motive in Education," *Forum*, 1925, **3**, 1, 40–45. In this important paper Dr. Miller examines the motives at work, consciously or unconsciously, in deciding the teacher's choice of his vocation. However suspiciously we may view the actual 'motives' suggested, there can be no two opinions on the wisdom of what Dr. Miller says by the way. Whether, for instance, there is an unconscious 'power urge' motive or not we can agree that the desire to force others to think as we do may be tolerable in the politician and pardonable in the evangelist, but in the man or woman who has access to the plastic mind of the child it is indefensible. Two characteristics of great educators are singled out by Dr. Miller as especially desirable: strenuousness and equanimity. The one implies capacity for infecting one's pupils with the feeling of the intrinsic worth-whileness of effort. This is a different thing from preaching a gospel of work *at* one's pupils. Nor is it attained by an emotional bond between adult and child. The struggle is in itself good fun: it is not engaged in "to please the teacher." The second character, equanimity, implies capacity for infecting one's pupils with a certain balanced attitude which only comes when the lesson has been learnt that life, in general, is trustworthy. Most of us have suffered in youth from exaggerated anxieties based on lack of knowledge and distrust of self: and few there be who have not been made still more anxious by the unwise though well-meant warnings of parents and teachers that "the branch will break and the dog will bite; the master will cane and the examiner will plough." How much better, Dr. Miller suggests, if we can communicate the sense that, though the world is in many ways incalculable, a gallant and high-hearted happiness is unlikely to meet with ultimate defeat. The equanimity, then, which is intended is not the product of callous insensitiveness, but of learning to—

"... meet with Triumph and Disaster
And treat those two impostors just the same."

"The whole art of teaching," wrote Anatole France, "is only the art of awakening the natural curiosity of young minds ... and curiosity itself can be vivid and wholesome only in proportion as the mind is contented and happy."

ARTICLES

THE DIGESTION OF CELLULOSE BY INVERTEBRATES

By C. M. YONGE, Ph.D., B.Sc.

There is no enzyme, so far as we know at present, in any of the Vertebrates capable of digesting cellulose; many herbivorous mammals, it is true, can split up the cellulose in their food, but only with the aid of intestinal bacteria. In the Invertebrates, on the other hand, no cellulose digesting bacteria have been found (possibly because they have not been very carefully sought), but a distinct enzyme (cellulase or cytase), which can digest cellulose, is present in a number of these animals. The literature is very scattered and, since the subject is one of some considerable interest, a short résumé of the present state of our knowledge will not be out of place.

We have no evidence of the presence of cellulase in any member of the Porifera, Cœlenterata, Platyhelminthes, Nemathelminthes, or Annelida; it appears to be confined to the Protozoa, Mollusca, and Arthropoda.

Protozoa.—Certain Sarcodina seem to possess the power of digesting cellulose. Cienkowski (1865, *Arch. mikr. Anat.*, vol. 1) has described how *Colpodella pugnax*, *Vampyrella spirogyræ*, and *Vampyrella pendula* feed on algæ by sucking out the contents of their cells. They have first to penetrate the cellulose wall of the algæ (*Chlamydomonas* and *Spirogyræ*) and, since they possess no mechanical means of so doing, this is probably performed by the action of a cellulase. Rhumbler (1898, *Arch. Entw.-Mech.*, vol. 7) has observed and figured *Amœba verrucosa* in the act of ingesting *Oscillaria* (one of the blue-green algæ). A long thread is taken in and rolled round within a digestive vacuole inside the animal. These threads are finally broken up into many small pieces by the action of enzymes, which must include one capable of digesting the cellulose wall of the algal thread. According to Stolc (1900, *Zeit. wiss. Zool.*, vol. 68), if a starved *Pelomyxa*, whose reserve of glycogen ("Glanzkörper") has entirely disappeared, be fed on threads of cotton or filter paper, which it takes in readily, the reserve of glycogen is re-formed. He was not able to observe the actual dissolution of the cellulose, but, after feeding with threads stained with Congo Red, he states that isolated vacuoles within the animal seemed to be coloured red, showing that digestion of the cellulose had taken place. Although it is naturally not easy to state definitely in the case of such minute animals whether any particular ferment is or is not present, yet the above evidence appears to be, if not absolutely conclusive, at least strongly indicative of the presence of cellulase in these animals.

As a result, very largely, of the work of Cleveland (1924, *Biol. Bull.*, vol. 46, and earlier papers), we know most about protozoan cellulase in certain Flagellates, belonging to the orders Protomonadina and Hypermastigina, which live symbiotically in the gut of Termites. Imms (1919, *Phil. Trans. Roy. Soc.*, B 209) expressed the opinion that there is a correlation between the presence of intestinal Protozoa in Termites and the habit of feeding on wood; Buscalioni and Comes (1910, *Atti. Accad. Giœnia Sci.*, *Catania*, vol. 3 (ser. 5)) having already found that the Protozoa ingest fragments of wood and, as a result, give a strong reaction for glycogen after staining with iodine. What they assumed, but did not prove, however, was that the Termites themselves could not digest wood. Cleveland has established a definite correlation between the presence of the Protozoa and the wood-feeding habit. There are four families of Termites, and he found that in three of them (Kalotermitidæ, Rhinotermitidæ, and Mastotermitidæ) Protozoa are always present, but that in the other family (Termitidæ) only three species out of seventy-five examined contained Protozoa which ingest wood. The first group of Termites feed practically exclusively on wood, but the more highly specialised Termitidæ rarely feed upon it; some species, indeed, never do so.

Cleveland succeeded, by incubating the Termites at 36° C. for a day, in killing all the Protozoa without damaging their hosts. These defaunated Termites all died within four weeks if they were fed exclusively on wood, but remained alive for an indefinite period if fed on humus or fungus digested cellulose—*i.e.* when the Protozoa were replaced by some other organisms capable of doing their work (no evidence of the presence of cellulose digesting fungi or bacteria in the gut of the Termites was found). When defaunated Termites were reinfected with Protozoa they were once more able to live on an exclusive diet of wood. The Protozoa can also be killed by depriving the Termites of wood, which appears to be the *only* food on which the Protozoa can live. They are extremely abundant and "*completely* fill the large and much distended gut of their host." Cleveland confirmed the observations of Buscalioni and Comes that the Protozoa actually ingest fragments of wood and, unlike the other intestinal Protozoa which did not ingest wood, contained large reserves of glycogen, which were still present after the host had been fed on pure filter paper for three months. As a result of these experiments, there can be no doubt that, though the Termites—in common, apparently, with the rest of the Insecta—cannot digest cellulose, certain flagellate Protozoa which they harbour in their intestines are able to do this, and it is only with the aid of these symbionts that the Termites can live on their customary diet of wood.[1]

Mollusca.—Biedermann and Moritz (1898, *Arch. ges. Physiol.*, vol. 73) were the first to demonstrate the presence of a cellulase in the Mollusca. They found that the alimentary canal of *Helix* contains a fluid which attacks hemicelluloses, though *not* " pure " cellulose in the form of filter paper or cotton. If a thin section of the endosperm from the seeds of certain Gramineæ (*e.g.* maize, wheat, rye, or rice) is treated with a drop of this fluid and then observed under the microscope, they found that the cell membrane was quickly dissolved, leaving only an open network unattacked. Sections of the endosperm of dates, brazil nuts, coffee beans, lupin and tropæolum seeds were treated in the same manner, the cell membrane being first dissolved and then the reserve cellulose which forms a thick layer on the inner surface ; vascular bundles and cuticularised parts were not attacked. The reaction proceeds in a neutral or slightly acid medium, but not in an alkaline medium, the end products consisting of glucose, galactose, mannose, and pentose. Müller (1901, *Arch. ges. Physiol.*, vol. 83) confirmed the findings of Biedermann and Moritz ; he found that the fluid in the gut of *Helix* digested cellulose which had been obtained from a potato tuber chopped up very fine and washed free from starch.

The presence of this ferment has also been demonstrated by a number of French workers. Sellière (1906, 1907, 1910, *C. R. Soc. Biol. Paris*, vols. 61, 63, 68) found that the digestive juice from the gut of *Helix pomatia* acted to a very slight degree on cotton fibres producing glucose, but that if the cotton was first treated with Schweitzer's reagent and then precipitated with acetic acid, or with zinc chloride, or with caustic soda or caustic potash and washed, it was acted on to a much greater extent, though a small white residue was always left unattacked. He was not able to make this treated cotton again as indigestible as it had originally been, although if it was desiccated in vacuo less than half the usual amount of glucose was produced after digestion. No separate enzymes could be isolated by subjecting the digestive juice to varying temperatures so that, presumably, the same ferment is responsible for the complete hydrolysis. Digestion proceeded in alkaline media though not so well as in the naturally acid medium of the gut of the snail. Sellière was unable to decide whether the reagents used modify the chemical constitution of the cellulose and so render it liable to be attacked by the ferment, or whether they merely destroy the structure of the cellulose fibres and so permit the enzyme to act upon portions which would otherwise be protected from it. The latter seems the more probable explanation, in view of the fact that the untreated cellulose is hydrolysed to a small extent, and there is always an unattacked residue even after it has been treated, and agrees with the evidence of Biedermann and Moritz that there are certain types of cellulose (hemicelluloses, etc.) which are attacked and others which are not attacked (" pure " cellulose). Bierry and Giaja (1912, *Biochem. Zeitschr.*, vol. 40) and Bierry (1914, *C. R. Soc. Biol. Paris*, vol. 76) have also reported the presence of this cellulase, which they call " dextro-cellulase," in *Helix*. They found that it acted on the cellulose (dextrane) present in the seed of the date and also on the cellulose in the seeds of *Phytelephas macrocarpa*, transforming them into glucose. They also give a detailed account of the action of the digestive juice upon a number of mannanes and galactanes (hemicelluloses), all of which are hydrolysed with the formation of mannose and galactose respectively. Billard (1914, *C. R. Soc. Biol. Paris*, vol. 76), who worked on the same animal, makes the extreme statement that the extract of the gut cannot be filtered through filter paper because it dissolves the paper before it has time to pass through it. He succeeded in digesting wheat flour, lentils, peas, buckwheat, potatoes, and haricot beans by means of the extract. Enriques (1901, *Mitt. Zool. Stat. Neapel*, vol. 15) found that pieces of the green weed, *Ulva*, were digested by the stomach juices of *Aplysia*. No doubt further research will reveal the extensive presence of cellulase in the herbivorous Pulmonates and Opisthobranches, where it is obviously of the greatest service in breaking down the walls of the plant filaments and so enabling the carbohydrates within to be digested and absorbed.

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[1] Since this article went to press Cleveland has published four further papers (1925, *Biol. Bull.*, vol. 48). He describes the method in which the Protozoa ingest wood, shows that Termites which have been fed exclusively on cellulose for a year grow and reproduce quite normally, and states that there is an absolute correlation between the wood-feeding habit and the presence of Protozoa at every stage in the life-cycle of the different " castes." He has also discovered that the Protozoa can be destroyed, not only by starvation and heat, but also by keeping their hosts, who are not affected, in an atmosphere of pure oxygen.

In the Lamellibranchiata the power of digesting cellulose is probably confined to one highly specialised family, the Teredinidæ. As is well known, these creatures bore into wood in the sea, and it has long been a disputed point whether or no they can digest in any measure the wood which they scrape off with their shell valves as they bore into the wood. Recently, however, a quantity of evidence has accumulated which would seem to provide sufficient proof that they can digest cellulose. All the wood shavings are passed into the mouth and through the entire alimentary system before they are expelled, by way of the exhalent siphon, into the sea. A large cæcum, not found in any other Lamellibranch, branches off from the stomach and is always full of wood shavings, although the stomach is usually empty. It has been suggested that this cæcum provides storage room for the slowly digested wood. The digestive gland is composed of two different portions, the functions of which have been the subject of a recent paper by Potts (1923, *Proc. Camb. Phil. Soc.* (*Biol. ser.*) vol. 1). The greater part is made up of tissue which resembles that found typically in the digestive gland of the other Lamellibranchs; Potts calls it "excretory," but it is probably concerned with intracellular digestion. The remainder of the gland, called "digestive" by Potts, consists of lighter coloured tissue (so that the two portions can be distinguished by the naked eye) made up of wide, but excessively thin-walled, tubules. Particles of wood are found in both regions, but only in the lumen of the former portion, whereas they can be distinguished actually within the cells of the latter portion, and are also ingested by free phagocytic cells, which are present exclusively in the lumen of this part of the gland—from which they probably arise by being nipped off from its epithelium. Histologically, therefore, there is evidence to show that in the Teredinidæ a portion of the digestive gland is specialised for the intracellular digestion of wood—and of wood only, since when living animals are placed in a suspension of Indian ink (or of iron saccharate, as I have myself observed) this substance is absorbed by the unspecialised part of the gland, but *not* by the other.

Harington (1921, *Biochem. Journ.*, vol. 15) made extracts of the gland and found that, whereas they would not digest pure cellulose in the form of filter paper, they could, apparently, form glucose out of sawdust. His experiments, unfortunately, are somewhat inadequate, as he was hampered by lack of material. More conclusive evidence of the presence of a cellulase in the Teredinidæ has been furnished by Dore and Miller (1923, *Univ. Calif. Publ. Zool.*, vol. 22). They made chemical analyses of the wood into which *Teredo* was boring, and of the borings which were ejected through their exhalent siphons. They found a very striking contrast between the constituents of the two. The following table, taken from their paper, summarises their findings (they assume that no lignin is synthesised):

DATA CALCULATED TO PERCENTAGES OF ORIGINAL WOOD.

Determination.	Series I.			Series II.	
	Woods, Pts. per 100.	Borings I, Pts. per 56·1.	Borings II, Pts. per 54·7.	Wood, Pts. per 100.	Borings, Pts. per 50·9.
Hemicelluloses . .	6·02	3·62	5·10	14·23	6·20
Cellulose . . .	54·74	11·79	10·99	47·45	10·96
Lignin . . .	30·60	30·60	30·60	27·84	27·84
Furfural yield . .	5·37	3·32	3·32	5·90	4·26

They continue, " On this basis, it appears that during its passage through the animal's digestive tract the wood has lost about 80 per cent. of its cellulose, and from 15 to 56 per cent. of its hemicelluloses, including from 11 to 40 per cent. of its furfural yielding constituents such as pentosans, etc." They consider that plankton must form the chief food of the Teredinidæ on account of the lack of protein in the wood, but that the additional carbohydrate supplied by the wood is needed to supply energy for the extremely strenuous boring activities ; unlike the protein, it can be completely oxidised, and there will be no need to dispose of any nitrogenous waste products.

Arthropoda.—In spite of considerable research, no trace of a cellulase has been found in the Insecta (apart from that supplied by the Protozoan symbionts of the Termites). Petersen (1912, *Arch. ges. Physiol.*, vol. 145) states that pollen grains pass unchanged through the gut of the honey-bee ; Biedermann and Mortiz (1898, *Arch. ges. Physiol.*, vol. 72) failed to find a cellulase in the gut of the mealworm, *Tenebrio*, while a number of workers have endeavoured without success to identify one in the alimentary canal of the silkworm and other leaf-eating caterpillars where it might reasonably be expected to be present. The only group of the Arthropoda, so far as we know at present, in which a cellulase is present is the Crustacea. Biedermann and Moritz (1898, *Arch. ges. Physiol.*, vol. 73) found that the digestive juice from the foregut of *Astacus fluviatilis*, the freshwater crayfish, dissolved away the reserve cellulose of the endosperm of seeds. The middle lamellæ of the cell membrane is left, only the outer layers (of hemicellulose) being attacked—unlike the action of the cellulase of *Helix*. Bierry and Giaja (1912, *Biochem. Zeitschr.*, vol. 40) confirm these observations. They state that the digestive secretion of the crayfish transforms the cellulose of the seeds of *Phytelephas macrocarpa* and of the date into glucose. Mannane from the same source was converted into mannose and the mannogalactanes of lucern and " Greek Hay " into galactose and varying amounts of mannose. The secretion of the marine crustaceans, *Maja* and *Homarus* (the lobster), though without effect on cellulose, acted on the mannane of *Phytelephas* but not on those of lucern and "Greek Hay."

Discussion.—The above summarises, so far as I have been able to discover, the full extent of our knowledge regarding the digestion of cellulose by invertebrate animals. It will be noted that cellulase is not present in the majority of Invertebrates, but only in those animals which are forced to rely exclusively, or to a very large extent, upon plant food, such as certain Sarcodina, some of the pulmonate and opisthobranchiate Mollusca, and the freshwater crayfish ; or which have adopted a highly specialised mode of life, like the Flagellates which live in the gut of the wood-eating Termites and are presented as a result with a practically exclusive diet of wood, on which alone they can exist, or the Teredinidæ which bore into wood and digest, intracellularly, a proportion of the cellulose in the borings which pass through the alimentary system. With the possible exception of the Sarcodina, they are all animals which have attained a high degree of evolution in their particular phyla.

Undoubtedly an especial difficulty in the investigation of cellulase lies in the uncertain knowledge we possess as to the exact chemical constitution of the celluloses and hemicelluloses, with the result that there is always a great deal of uncertainty and contradictory evidence (particularly, it will have been noted, in the case of the cellulase of *Helix*) as to exactly what kinds of cellulose are attacked and in what proportion.

There is, therefore, much to be discovered, both with regard to the nature of the various celluloses and the nature and prevalence of the enzymes which attack them, and also with regard to the presence, in the more highly organised Invertebrates, of intestinal bacteria and symbiotic Protozoa capable of digesting cellulose.

COLOUR AND OTHER CHANGES IN THE FLAKED SURFACES OF FLINT

BY J. REID MOIR, F.G.S., F.R.A.I.

IF a large series of flint implements, comprising examples of every prehistoric culture found in England, be examined, it will be seen that, speaking generally, the specimens can be divided up into three distinct groups, by the differing colours exhibited by their flaked surfaces. These groups are (*a*) implements that range in shade from a dark mahogany brown to a light chestnut brown, (*b*) specimens that show either a streaky coloration of black and white (the well-known " basket-work patination ") or a dense blue or white, and (*c*) implements that exhibit the unchanged colour of the original flint. Such an examination will show, also, that this grouping of the specimens, according to their colour, has grouped them, moreover, according to their types, and that those showing coloration (*a*) are of Eolithic, Pre-Chellian, Chellian, and Early Acheulian forms; those exhibiting coloration (*b*) are of Late Acheulian, Mousterian, and Upper Palæolithic types; while those showing coloration (*c*) are referable to the Neolithic period. In any large series of flint implements there will be exceptions to this classification. Thus, in the early cultures grouped under (*a*), there may appear a few specimens that either do not exhibit any colour change upon their flaked surfaces, or show a blue, or a white patination, or, in the cultures grouped under (*b*), some specimens may show a chestnut-brown colour or no colour change at all, and in group (*c*) there may appear implements showing a white or a blue patination. But though this is the case, there cannot be any doubt that the majority of the oldest types of specimens are grouped under (*a*), the less ancient under (*b*), and the latest under (*c*). When, however, the examination is carried farther, we realise that, in group (*a*), the oldest implements, the Eoliths and the Pre-Chellian specimens, exhibit the darkest shade of brown, the Early Chellian a less dark tone of this colour, while the Later Chellian and Acheulian implements are of a much lighter, chestnut-brown, shade. Thus it becomes clear, in regard to the specimens of group (*a*), that a certain type of patination is indicative of antiquity, and that the conditions giving rise to a brown coloration upon the flints operated with progressively less intensity during the great period of time represented by the cultures in this group. Though our present knowledge of the remarkable changes of colour that take place in the flaked surfaces of the flint—the results of which are known as " patination "—is very small and inadequate, yet one or two facts, ascertained by experiment, have enabled us to form some idea of how a few of these changes may have been brought about. It is known that the interior of a freshly broken, sound flint of good quality is very hard and the attempts to colour such a surface by placing the specimens in various staining agents—and without having resort to heat in the experiment—were unavailing.

When, however, the flint was subjected to the fumes of hydrofluoric acid for a few moments it was noticed that the specimen first became blue and, as the process was continued, a dense white. When this stage was reached the flint was again immersed in a stain, and after a time became definitely, and permanently, coloured. Thus it is obvious that the effect of the fumes of hydrofluoric acid produces a change in the surfaces of the specimen, and enables them to absorb a stain. Judging from this evidence, it seems reasonable to suppose that the flint implements that exhibit a dark mahogany or other shade of brown have gone through a similar—though much less rapid—process to that described, that is to say, they were first subjected to some solvent which made their surfaces white and absorbent, and that they were afterwards immersed in some material which permanently stained these surfaces. Now, upon the surface of the ground in many parts of the country are to be seen large numbers of humanly flaked flints that are coloured either blue or white. If one of these specimens is broken, it is seen that the interior of the flint has suffered no colour change and that the patinated surface is visible as a thin layer surrounding the fractured area. Further, an examination of these blue and white flints will show that the former colour is due to the fact that the patinating process has not progressed very far, and that the blue appearance is due to a thin film of white spread over the original black surface. When the process of patination has progressed so that the black of the original surface is no longer partly visible, then the specimen appears as a dense white. So far as we know, this change occurs only upon (*a*) flints exposed upon a land surface or (*b*) buried in certain pervious soils, just beneath such a surface; and so it is supposed that the ancient flint implements of group (*a*) were—as is in every way likely—exposed, for a prolonged period, upon, or in, a land surface, and there acquired a white patination. Eventually, they were buried beneath deposits which, it seems, must have been very rich in salts of iron, and that their long sojourn in these ferruginous beds had the effect of staining them. But, as the oldest flints in group (*a*) are the most stained, and as the stain gets progressively less in the later members of the group, we conclude that either the bed that sheltered the Eoliths and the Pre-Chellian specimens was richer in iron salts than that which sheltered the Early Chellian, while those deposits which sheltered the Later Chellian and Acheulian implements were still less ferruginous, or that these latter specimens were not exposed sufficiently long to atmospheric conditions upon a land surface to have produced, upon their flaked surfaces, the white, absorbent patination such, as is known, readily takes a stain.

When we pass to group (*b*), containing specimens of Late Acheulian, Mousterian, and Upper Palæolithic types, which exhibit either a streaky coloration of black and white or a dense blue or white, we see that, as in group (*a*), these patinations are, generally speaking, more marked upon the earlier members of the group, and that, in consequence, patination in this group is again indicative of antiquity. The streaky " basket-work " coloration is remarkable both as regards its mode of occurrence upon flint implements and its origin. So far as my knowledge extends this particular patination is not found upon any specimens earlier in date than Late Acheulian, and one must conclude that the conditions giving rise to it had not appeared until that period. Many Late Acheulian implements, however, exhibit basket-work patination in a well-marked form, but it is in the succeeding Early Mousterian phase that it is most definite and noticeable, while in the succeeding culture stages it becomes less and less apparent. The exact cause of this peculiar coloration, which takes the form of white streaks—which meander over the otherwise unchanged surface of the original flint—is not at present known, but it would appear probable that it may have been given rise to by various causes. I have been able to examine a great number of flints from the Upper Chalky Boulder Clay of Suffolk, and other deposits, which exhibit this coloration, and this examination has shown me that the white streaks certainly differ in their origin. The great majority appear as white, wavy lines in the surface of the flint, and exhibit no other peculiarities, and the origin of such lines is very obscure. They may represent areas in the flint surface which for some unknown reason are less hard than that surrounding them, and have thus become affected by the agent of patination, which has failed to affect the harder portions of that surface, or they may be, as it were, " roots " of the cortex of the flint, exposed when the specimen was flaked, or they may have had their origin in the dissolving action of vegetable roots. Personally, I favour this last suggestion, because I have sometimes found pieces of fossil bone associated with the basket-work flints, and these bones exhibit, on their surfaces, a series of wavy lines, which are etched out and appear almost certainly to be due to root action. In the case of the flints—as would be expected—the white lines are not etched out, but this is due, in all probability, to the greater hardness of the flint surfaces as compared with those of the bones. A certain number of these white lines have, however, developed where the flint surface has been scratched, because, under a lens, the path of the agent of striation can be clearly traced by observing the " centipede marks " produced upon a flint surface by the pressure of a point moving across it under pressure. Such lines are, usually, more or less straight, and thus differ from those which follow a meandering course. In the experimental work I carried out it was found that when a piece of freshly broken flint was struck with another stone, and incipient cones of percussion produced upon it, or when any bruising of the surface of the specimen occurred, these bruised areas were very susceptible to the artificial patinating agents used in the experiments. In fact, it became clear that these agents " picked out " such areas and whitened them, while the other, unbruised portions of the flint were not affected. The same order of events evidently obtained in the past when the implements were striated and then subjected to some agent of patination.

When a flint exhibits merely these straight white lines due to striation, it cannot be said to show a true " basket-work " patination; but in some cases the lines on one and the same specimen may be of both kinds. A further suggestion regarding the origin of these white lines is that they may be due to fossiliferous inclusions in the flint, which would give rise to soft areas susceptible to patination, but I do not regard this as at all probable. If one of the specimens exhibiting basket-work coloration be broken across it is seen that the whitened areas are of exceeding thinness and do not penetrate far into the flint.

The late Mr. E. T. Lingwood found that when flints patinated white were immersed in oil for some time, the patination disappeared, but that, after the specimens had been taken out of the oil and exposed to the air for some time, the white coloration, in most cases, returned. But, with some of the flints with which he experimented, the surfaces did not return to their former condition, but showed a streaky coloration. These specimens he spoke of as being partly " de-patinated," and suggested to me that the basket-work patination was the remains of a former wholly white surface.

In some instances, the unflaked cortex of the specimen also exhibits the basket-work patination, though it is not so noticeable here as upon the flaked surfaces, and, after full consideration of the whole problem, I incline to the opinion that this peculiar coloration has been due to root action, though why such action should have manifested itself so markedly in Early Mousterian times is at present an insoluble problem. The other specimens in group (*b*) that are coloured a white or a blue can be explained upon the supposition that they had lain upon a land surface for a sufficient period to have these colours imposed upon them, and were then incorporated with the deposits beneath, and in which they are now found. The Neolithic implements included under group (*c*), which do not show any colour change of their flaked surfaces, may be regarded as those which have not been exposed to atmospheric conditions long enough to allow of the patinating process having any effect upon them. Thus, in these three groups of implements, we see that the earliest distinctly tend to exhibit an ochreous colour, that the less ancient do not show this tendency, but exhibit a " basket-work," or blue, or white coloration, while the latest of all do not show a colour change of any kind.

Sometimes one finds, in a very ferruginous deposit, flaked flints which are either blue or white in colour, and these have evidently not been stained by the material surrounding them. At first sight this appears very difficult to explain, but an examination of these particular specimens will generally show that their flaked surfaces carry a well-marked glaze, and when this has been imposed upon a flint it appears to make it impervious to any further staining agents. The origin of this glaze upon flints, which is best seen upon the well-known specimens from Savernake, in Wiltshire, is at present uknown, but various suggestions, such as (*a*) the action of blown sand, or (*b*) of running water with sand in suspension, and (*c*) redeposition of silica, have been put forward to account for it. So far as I am aware there is no definite evidence in existence to show that flints patinate a white or a blue colour while buried deeply beneath the surface. On the other hand, there would appear to be very good reason to believe that these colours are imposed on specimens lying either upon or just beneath that surface. In the first place, in many parts of the country there are to be seen upon the surface of the fields vast spreads of flints exhibiting a blue or a white coloration, which would seem to point to the fact that the patination of these specimens took place in the position where they are now found. Secondly, in one of the great workshop floors which I investigated at the famous flint-mines at Grime's Graves, Norfolk, where the mass of the flint flakes and broken pieces averaged three to four feet in thickness, it was noticed that the flints nearest the surface of the ground were white on both surfaces, those a little lower down were white on the upper surface and blue underneath, those lower still were blue on the upper surface and black underneath, while those at the bottom, resting upon the white chalk, were black and unchanged on both surfaces. This evidence seems to show clearly that the agent of patination was acting from above downwards, and that its effect became less and less, and finally ceased at a depth of about 3 feet from the surface. Incidentally, this discovery also shows that, at the site investigated, the white chalk did not whiten the flints in contact with it. Unfortunately, we do not know what it is in nature that patinates flints, but it is evident that some widespread cause has been, and no doubt is still, in operation. It has been suggested that rain-water charged with CO_2 might, in the course of a prolonged period, produce patination on flints, and this view would seem to be, in a measure, supported by the apparent slowness with which the process acts. For instance, an examination I have carried out of numerous churches, and other ancient buildings built of dressed flint, has failed to reveal to me any really noticeable colour change in the exposed surfaces of the stones, and the latest flint implements found upon the present land surface, which must have been exposed there for several thousands of years, are not patinated. The only experimental evidence known to me, which perhaps supports the idea that rain-water charged with CO_2 may have been the cause of the patination of flints, was provided by the late Dr. Canton, who placed some newly broken, sound black flints in a gasogene for about twelve months, and, at the end of that time, a very slight bluish tinge was to be seen upon portions of the surfaces of some of the specimens. It is known that certain flints dug from the chalk by the gun-flint makers of Brandon show, soon after having been broken and exposed to the air, a bluish tinge, but, regarding this, it can only be said that this is not the case with other specimens from different parts of the country. The flints found in the workshop floor at Grime's Graves, already mentioned, that show a dense white patination on their upper surface and a light blue upon the lower, are what is known as "doubly patinated" specimens, a somewhat unsatisfactory term. Now experiment has shown that the most patinated is the softer surface of such a flint, and in the vicissitudes through which the specimen passes, such as rolling in a river-bed or being subjected to striation, the fact of the differing hardness of the two surfaces will make itself manifest. Thus, it is possible to see some Palæolithic implements exhibiting two unequally patinated surfaces that show, on the softer side, much wear and deeply marked striæ, while the other, harder surface is comparatively unaffected. The difference in appearance of the two sides is, in fact, so great that unless a careful examination is made the conclusion might be drawn that the deeply patinated surface is actually much older than the other. Occasionally, one sees an implement where the two surfaces are of different ages, but, in my experience, this is rather rare. There would seem no doubt that the effect of patination is to slightly dissolve the surface of a flint, and I have seen specimens taken from an undisturbed occupation-level of which the upper patinated side appeared to have been subjected to slight amount of rolling, but which was due solely to the effect of patination. In every case which has come under my notice of doubly patinated flints occurring in an *undisturbed* floor, the patinated side of the specimen has always been that which is nearest to the surface soil, and, if this is true in all cases, then we know that when we find a palæolith in a deposit of gravel, which shows a double patination, this specimen was originally on, or just beneath, a land surface, with the side that is most patinated uppermost. In the Warren Hill gravel in north-west Suffolk there are found a large number of Palæolithic implements exhibiting double patination, and many which show a peculiar speckled yellow and black coloration. In most cases, this latter appearance has been produced by the flint first being struck by other stones during rolling by water action, and incipient cones of percussion formed in its surfaces. These bruises have afforded areas where the patinating agent could take effect, while the other, unbruised portions of the flint show no colour change.

From the foregoing brief account of some of the colour and other changes that take place in the flaked surfaces of flints it will be realised that the subject is somewhat complex, and, I fear, very little understood. The whole question of "patination" should be investigated by competent chemists and physicists, and until this is done we shall not attain to any understanding of what is, without doubt, a very important, and practically unexplored, subject.

THE SCIENTIFIC VALUE OF COLOUR IN INDUSTRY[1]

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THE development of that absorbingly interesting phase of modern industry now generally termed "scientific management" is one full of both scientific and artistic scope, for use and for further research and invention. When the first results of early experiments became manifest, even the experimenters were surprised at some of their findings. Age-old traditional methods and tools were proved to be not the survival of the fittest by any means, but merely the survival of the accepted and ordinary normal workers' idea of tool or method. This long history of empirical development had in many instances shown but the slightest perceptible improvements, during quite long periods. The hammer and the square suffered but slight change in their actual use, and not much more in their material and mode of manufacture, until quite recently. Before the days of the mass-production in small-tool factories, the artisan had to get his hammer made by a local smith, and possibly made his square himself, a long and arduous job to get anywhere near correct.

The methods of scientific factory investigation, therefore, took up the problem of the workers' tools, his machines, and also the worker himself, and in spite of certain understandable opposition on his part, succeeded in showing beyond controversy that the former traditional empirical methods were insufficient to meet modern needs, and were moreover definitely wasteful of time and energy in labour, and also of material and results.

These researches did not end here, but then spread, in particular when new factories were under consideration, to working out a proper "progress" scheme for the whole factory. The building was no longer left to the whims of the architect, and his preoccupation with "styles" from museums, but the managing engineer took a large share in the problems of functional planning. Thus, the confusion that formerly existed

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very generally in buildings which had been adopted and adapted to factory use, and which sometimes had additions built on to them quite casually when required, is now a thing of the past, except in a few old-fashioned places here and there, which are inevitably losing ground by their lack of modern methods and sound organisation.

Developments had got so far, before the wartime era necessitated a tremendous speeding up of certain productions and a great and continuous concentration of effort in definite lines. While time could not, in the majority of places, be spared for new buildings, it became definitely necessary to study method and eliminate every obvious hindrance to speed and surety of production. From costing methods and interchange of technical data, to the introduction of skilled professional technical teachers, these improvements then turned to that phase which became known as welfare work, and which has unfortunately almost disappeared in Great Britain, except in relatively few factories owned by enlightened firms who realise fully the great value it has in maintaining a long-term staff, all in a contented state.

The last of the widespread developments in factory efficiency has been in two directions, in connection with the actual buildings rather than with any concern for the workers as such. Necessity for economy having become manifest, it has been found possible, by deliberate design in the painting and in the illuminating, to effect considerable savings in the light bill. It is these factors of colour and light, which have been the last to be scientifically considered, that we will deal with here. Yet it seems strange that what are in actual fact two of the greatest and first necessities of all industry should yet be the last to be subjected to closely detailed scientific inquiry, and that when it did finally occur, that it should be compelled rather by stringent need for economy than by a normal desire for increased efficiency, through any means possible, in all the factors concerned in modern production.

The climate and the seasons of Great Britain being what they are, there is great need for artificial lighting in very many industries. And the cost of light was found too much in proportion to the service it gave. Lighting systems were out of date, inefficient, and wrongly designed ; while the interiors of factories and warehouses had simply been painted any colour which the foreman had happened to ask the decorator to put on, for the amount of money available. New lamps were put into old fittings ; light was dispersed instead of being concentrated ; current wasted in naked lamps, often in the wrong place. Whitewash might be slapped on once in the statutory seven years. Plant went entirely unpainted. It was all empirical; it did not seem to have any direct bearing on economy, and not any at all on production. But it was eventually found that the right paint and the right light in the right place gave more service at the same or even less cost. The reasons for this are explained below.

The value of colour in industry lies in its universality, as also that of light. All humanity live in and by light, which gives us colours. Whether we design it so or not, colour enters into homes, stores, offices, and factories, in every object in them, and in the structure itself. We cannot avoid colour any more than light. Its very ubiquity has prevented it being turned to the fullest scientific industrial account.

The human mind gains the major part of its life experience through and by colour and light, by vision. Hence the power of the cinemas, even without the beauty of full colour. Hence the great attractions of theatrical spectacles, with their frequently well-designed displays of light and colour, often the best part of such shows. If colour can exert such attraction in this particular phase of art, it were folly to neglect its power in the realm of industry. It has, of course, been well used by designers of advertising for a good period. But that is the selling end of the job. In the more important factory end and the midway necessities of transport, colour has scarcely been utilised at all in a complete psychological manner.

The eye differentiates all visible objects by form and colour, from infancy, through repeated experience. Qualities at first known and learned by touch are later recognised by sight alone. The position of objects in space is gauged by colour as well as form. All of this is practically subconscious. Except in the case of the trained artist, few people consciously realise what work the eye unconsciously does for them through long habitual training. Therefore colour has been neglected in the factory. In the store it is used as an artistic element. Its scientific value is scarcely realised, in its power in displaying or suggesting quality, even as form suggests quantity.

The central power of colour lies in its value for visual cognition and recognition. Colour properly placed on form emphasises that form. Colour is the true base of publicity, the science and art of making things and facts visible. Its use is to make things easy to see, easy to grasp, easy to understand. It is done mainly by proper contrast, in the proper place, as the contrast of black print on white paper: of red light or green on the railway, and a thousand other ways, usually isolated and customary rather than scientifically planned. Nature makes things visible or obscure by means of light and colour; we must use her principles but not her details for our human arts. We must use colour scientifically for publicity, at work and play. The adequate use of scientific colour and lighting means improvement on very many phases. These include increased efficiency and ease in working; increased economy in overhead charges; a more contented staff; and a great diminution in the proportion of accidents, whether those injurious or fatal to workers, or costly damage to plant. All this psychologically follows on the introduction of scientific publicity in terms of light and colour. Darkness and dirt inevitably spell confusion, waste, delay, accidents, damage and disease. Sound and scientific organisation necessitates their elimination from industry. We need not trouble much about artistic industrial colour; let us have it scientifically adjusted to human beings: the rest will follow.

Publicity in the widest sense is of course of much vaster scope than merely advertising, and has a greater utility than solely in commercial aims. Nature has and uses methods of publicity, we are told, when her flowers are brightly coloured to attract bees—that is, if bees really do see colour in the same way that we do. It is much more probable that flower colours are due to expression of the natural quality of some other power of attraction which is more obvious to bees, and far less so to us. Artificial flowers do not deceive bees.

But, in the realms of human industry and art, it is both necessary and advisable that publicity methods shall be fully and adequately utilised. This does not mean a conscious and widespread commercial effort to advertise. It means the scientific use of art, in form and colour, to make the world a more pleasant place to live in, to work in, and an easier place to find one's way about in, when in strange cities or buildings.

Publicity is the antithesis of camouflage. During a war, each side endeavours to hide its movements, its possessions, and its aims from the other crowd, who also do likewise. Upon their skill in concealment of facts, and in distraction and diversion of the attention of the opposition crowd, much of their success, or alternatively their lack of complete failure, directly depends. Curiously enough—and it comes as a shock to the unobservant—the *camoufleur* used bright colours much more frequently than dull colours, more especially at sea. It was actually found that bright colours in small quantities are more confusing, because they allow of more immediate contrast with each other, apart from their total contrast with surroundings. It was found that the deliberate contradiction of form by broken and wrongly emphasised colour gave the best stationary camouflage possible, while for a moving object broken forms with sharp colours, still bright, proved best.

Yet we find some people seriously setting about publicity, and spending money and time, without any clear notion of what the real foundational principles of publicity really are. This results in their sending out advertising work which actually comes nearer a definition of camouflage than of real publicity. They use confused forms, and realistic colour with a multitude of details ; realistic pictures that may pass muster when seen inside an office, but which, when seen in actual use in the street, or in some periodical against others, are lost. There is too much unintentional camouflage in industry. What is needed is breadth, clarity, strength, brilliance of colour, a good proportion, and not too much detail at a time.

The aims of publicity are numerous. The decoration of nature is always the combination of scientific colour with beauty of tone and juxtaposition. All natural colours indicate some function or quality of the object which produces them, and they are never accidental ; even when a divergence from type produces a divergence in colour, it is because of difference in function in some way. The quality of the object is balanced by the quality of the environment, both revealed by light. But man has more uses for colour than nature, for she does not trade nor make profit, she is a solely co-operative concern who gives with one hand and takes away with the other. Her most marvellous and most notable colours are the shortest-lived, as in the sunrise and sunset, or smaller and more enduring, as in a flower or a gem. In art we do best not to copy the detail of nature, but to study her inward principles, and use their laws to gain our totally different effects, since working in natural material we must use natural law, which is exactly the same as artistic law, no more, no less, but applied in relation to the needs of humanity.

" Publicity," in its widest sense, means making things visible or public to the eye or ear. It is another word for art in its definitely social aspect, the art of telling somebody about something. Advertising is the conscious way of doing it, but the decorators' way is often subconsciousness. When we erect a building of any kind, it is intended for the use of human beings, and its structural proportions must be designed with that in view, and also its colour with the internal lighting. It is then the duty of the decorator to preserve the walls, to beautify their surface in doing so, at the same time preserving the great amount of daylight that comes in, or making the most of artificial light that is provided. Actually, decorating and lighting must work hand in hand, for neither can function at its very best without considering the other. Light and colour are the right and left hands of decorative art, but they are the dual necessities of the more fundamental necessities of scientific art—the art of preserving the fabric, while at the same time catching and preserving daylight and also artificial light, The factors of publicity include, as well as light and colour, either artificial or natural, the human eye and the mind, with all its peculiarities and its previous experience, varying as it necessarily does in each individual, which fact accounts for the natural divergences in " taste " in colour and art.

Without light there is no colour, but without the eye there might just as well be neither light nor colour for all the observation that could be made. And without the mind, there can be only a momentary and mechanical register of a mere fraction of the beauty of colour, scientifically obtained, without either discrimination or wilful selection—as by the camera. The eye and the mind simultaneously train each other to observation from babyhood, until we become adults and have quite forgotten all the hard work of learning to see—unless we turn to study art, and find that we have not learned to see a quarter as much as we thought we had, and find that we only partially see, after all. Yet true seeing means true knowledge.

The act of seeing is to note and to judge the relations which we observe between certain objects, and their colours, according to the light falling on them, which, reflected to the eye, renders vision possible. Each judgment is necessarily made with reference to all past experience, usually quite subconsciously. We can take in only one or two new aspects of a thing at a time, whether by eye or mind. The more experience we have had of seeing and observing colour very carefully, the more easily do we judge correctly concerning any new item or combination which we meet, and the more surely we can use it in our work. But how many people can accurately remember a colour ?

The well-trained artist, understanding something of the interrelation of these many various factors, will deliberately arrange them in accordance with the total effect desired. According to the light available, he will select and apply colour, to obtain the desired result. He will obtain the best scientific conditions, and then go beyond mere utility to the beauty of good decoration, which costs so little more in labour, but yet achieves so great an effect on the more subtle parts of the mind. For harmony in colour induces harmony in the mind, and as most of us react in the same way to most normal stimuli the likenesses are more frequent than the differences. Abnormal colour schemes are thus only desired by or suited to abnormal people, although a brief experience of abnormal colour is often exhilarating, just as a brief experience of some unusual beverage may be. Neither are fit for regular use.

The Psychological Methods of Publicity or visibility may be obtained in two ways. It can exercise its effect on the mind consciously or unconsciously. It is possible and usual in most commercial use of colour to have both effects coincident. This is due to the fact that we are able to give an instinctive attention or an habitual attention, to which is superadded a conscious attention, often focussed on something else, in entire ignorance of that which the lower attention has noted. A simple instance of this is the dual act of turning in the gateway of our own house while talking vigorously with a friend. The act of walking and of turning in at the right place is performed quite subconsciously, when our higher attention is concentrated on our conversation.

In a similar way, methods of using of colour with which we have ourselves been familiar for years do not attract our attention, although they will attract that of others. The power of much advertising is greatly discounted by too great a familiarity with the advertisement or even the object itself. We see something we have seen many times, and subconsciously do not receive stimulus enough to arouse our conscious attention, so that we have no curiosity concerning it. The tourist sees more of external London than does the Londoner. If we saw all the street lamps painted a vivid scarlet, we should notice it, but only at first. We see all the pillar-boxes coloured bright red, and therefore never notice them, so that we might pass several when staying at a seaside resort, and when later we wish to post a letter cannot remember exactly where one was.

The type of publicity that desires to pound away into the subconscious mind of the man in the street must not be surprised if the message gets there—and *stops there* ! It is novelty that attracts curiosity, the old thing in the new way. Art is displayed in the treatment of the problem in relation to the end desired. Differences may be slight, but must be notable.

Colour may be used to attract or to warn. Commercially the former is most required in advertising, while warning is frequently needed in factories. Colour to attract must be visible, bright, pleasant, and not too customary. To warn, colour must be sudden and startling, if not on a conventional and accepted mode, as red lamps. Light and colour exercise a reciprocal influence on each other, especially when within a building. The use of colour when deliberately applied in a scientific manner is to differentiate forms from other forms, or spaces from other spaces. The use of colour when artistically applied is to make this differentiation pleasurable and beautiful, in addition to the mere visual efficiency achieved by science alone. Thus the psychic element of pleasure is added to the merely physical-utility.

Without colour, we have to depend on light alone for help in observation of form, and if all objects were uniformly coloured this would be very difficult, particularly in the open, and under a diffused light. Thus an object such as a sphere, suspended before a background of the same colour as itself, and lighted uniformly from all sides, with the background receiving the same light, can scarcely be distinguished. Uniformity of light and uniformity of colour are the characteristics of interstellar space, and as such cancel out into complete invisibility, except sources of light energy, or reflectors of it.

When we have through sunlight or through well-planned artificial light a *uniformity* of illumination, then we have to obtain a *variety* of colour in order to make observation—and therefore movement and action in our surroundings—as easy as possible. Dirt and soot are respectively the natural and the unnatural enemies of colour, in our cities, by reducing it down to a dull uniformity of black grime. Our colour must not be varied, however, in just a whimsical or a merely fashionable manner ; it must be so ordered as to definitely make visible and emphasise the functional parts of buildings and of machines.

The definition, therefore, of what publicity in colour is actually, is thus shown to be the careful and scientific application of selected hues to chosen parts of an object, such as a building or a ship, to ensure that the full use of the structure is made as easy as possible. The colour may be added pigment, or may be the natural or artificial self-colour of the material of the structure. When paint is applied, it should serve a triple purpose. It is first usually essential to preserve the material of the structure from rapid decay ; it is next necessary to provide " publicity " or " visibility " ; and it may finally rise to an artistic level as decoration by further care in the harmonious selection and juxtaposition of colours and shades. But if this final aim be pursued in ignorance of the first or second, then we may justly criticise such decoration in most adverse terms.

The practical methods to be adopted in any form of publicity will obviously depend on the aim. According to the function, so will be the form, as in all nature and all good art. So also will materials be chosen, and the time and place for their operation. It is fatal to good art to accept the imitation of nature as art, and here we meet the first great difference between art and nature in achieving a purpose. Nature can apparently do work very efficiently in an unconscious mode, incomprehensible to our minds. But we, if we desire to obtain a certain result, must know consciously what it is and also how to reach it. Whether our object is to be attained through other persons, attracting them subconsciously or consciously, we cannot do it well without being fully conscious of our aim, our method of work, and how to use it. Art is not done by dreaming, but by very vivid attention. In other words, we must make some careful and systematic study of the ways in which colour and form subconsciously influence ordinary people, so that we can consciously utilise those principles in our daily work.

In the commercial publicity of shops and stores, it is eventual sales that are desired. To obtain this result, several factors are necessary. Having made goods or supplied services, the public must be told what interest they have in knowing about them, and how they will be benefited by the use of such things. Thus, information, then suggestion and persuasion, and finally reminding, must be used in turn, whether personally or by some artistic means. Equally there must be avoided any depreciation, overstatement, or false statement. Obviously the first aim is best achieved by pleasant means, information given cheerfully, pleasant persuasion, gentle reminding. Information is best given clearly by clear forms and clear bright colours, well lighted and in suitable places. But the latter aims make themselves unpleasant by unwanted or undesirable information, aggressive suggestion and impudent persuasion or noisy and blatant reminders; and when art is used, make that art seem unpleasant too, by their association. Few men in civil life would buy or wear khaki-coloured clothing—because the colour has unpleasant associations for most men.

In our present system of civilisation, however, undue emphasis has been placed on the selling end of the system, in particular relation to the use of art as a factor in salesmanship. In the place of origin of commodities, however, we find that science has been emphasised more, and frequently art does not appear at all. An endeavour is now being made to place the whole course of industry on a better balanced system, and we thus find the introduction of scientific psychology, as applied to art in form and colour, when used for selling, while we can now see the beginning of a system of using well-organised art in the factory as an aid to production.

The objects of colour decoration with applied pigments in paint form have been described. They must (*a*) be preservative, (*b*) have cognitional or visibility value, and (*c*) have decorative or artistic value. Now, if it is found advisable to utilise all the resources of decorative art in a store for selling, because of the pleasurable effect they have on the buyers, it is surely no less advisable to have at least some care for colour and lighting effects in a factory or warehouse, where the same art will exercise the same influence. Doubtless, decorative work on the same scale is uneconomical and thus impossible. But when it has been found that actual economy has resulted from "painting light" by reducing the consumption of artificial light, and by postponing for a few minutes daily the time of lighting up, by reason of the increased period of daylight use, it has been generally agreed that care in simple decoration is very well worth while. The paint and the labour cost no more—the only extra is the use of skilled brains to decide what paint shall be used.

Yet there is still a further influence. That is the emotional condition of the workers. It has been observed, for instance, that towards the end of the day, when light fails, that their energies too have dropped, and there is a very definite drop in the graphic curve of production. This has been obviated by the use of properly designed artificial light. The increase of illuminating power has been more than balanced by increased production for the period of use of the installation. Any source of artificial light, however, is only a part of the problem, which only concerns a few hours of morning and evening. Colour problems, on the other hand, are potent every hour, all day, every day.

Sunlight, coloured artificial light, and pleasing schemes of colour decoration are now among those factors of life which are admitted to have a beneficial influence on health. Their financial value is such that people will gladly pay to get to places where these benefits exist. Medical treatment realises the value, and they are included in modern therapeutic treatment. Just as their presence will aid the restoration of lost health, so they will maintain normal health. And the absence of good light and colour over long periods will inevitably destroy health and efficiency. The psychic effect in the factory is as marked as the physical effect. Bad ventilation slackens speed physically, and bad colour puts on a psychic brake. Good colour and good light are a continual approbation to the unconscious need of the worker.

The lack of interest which many workers display towards their work is in no small part due to their uninteresting surroundings. Women in particular are very susceptible in this respect. While they were engaged on war work it was noted that the supply of a mirror, and singing while at work, helped very considerably to cheerfulness, and thus to better work. There is no question that we all work better when we feel more cheerful. We work better on a sunny day than on a foggy and dull day. It remains for scientific management to rise from the consideration of materials, of labour reactions in muscle movement, to psychic reactions arising from light and colour. They are more subtle, but none the less powerful. We all feel more pleased to be in a garden than in a coal-cellar—but how many factories, offices, warehouses, and stores resemble the dingy drabness of a gloomy cellar, depressing in every way! This is neither necessary nor right.

It is possible to have "sunshine" by a very near approach to it, in psychological suggestion, in the factory as a regular thing in all but a few exceptional types of place. Thus, additional to the merely negative side of using colour in aiding economy by avoiding waste of light, there exists the very powerful positive value of light, together with the powerful aid of colour, by which an increase of effort can be maintained. Not only that, but in many factories where unskilled, or relatively unskilled, labour is general, there is a large labour turnover during the course of a year, which means training of new workers. This can be reduced by a full recognition of the very simple fact that human beings have a natural preference for working in a pleasant place, rather than an unpleasant one. Many employers have not the faintest conception of the reasons which will induce people to leave a job for another of exactly the same kind.[1] It is very often, especially in the case of women, or of highly skilled men, some quite minor factor which has become disagreeable to them: which they do not themselves think of altering or asking for alteration, and therefore leave.

So far, colour has referred to schemes of decoration, obviously in the main for walls, the wood or metal frames of windows and doors, etc. But in places with much machinery, close attention to the colour of the machines is of great value. Good visibility is all-important here. It is essential for the operative to be able to easily see without strain the object being worked on, and the action of the machine, against the background of some other part. It is amazing how many workers are forced to labour in situations of a most inconvenient nature, all because the supposed organising power of the employer or his manager is incompetent to produce the best possible conditions for production. Why complain of low production when conditions which are not in the workers' power to alter are themselves inefficient? There is no sumptuary law against comfortable factories and offices.

The little that has been written here on this vast subject of efficiency in colour will indicate the scope for treatment of our environment on a rational basis, apart from all those freaks and fashions which have little real human value. Not only in modern industry, but in buildings of every kind, is this skilled and thoughtful attention to light and colour very necessary. Schools in particular are great sufferers from vile and ill-conceived colour schemes, and atrocious " lighting," concerning which the occupants, whether teachers or taught, exercise not the smallest voice. Offices of all kinds, particularly in our great cities, are too often dark and gloomy dungeons, which make their inmates truly thankful to escape from them on the stroke of time. If employers want their people to take any real and live interest in work, they must do something definite to make the work more pleasant, by at least having their surroundings reasonably pleasant to work in. It is not difficult ; it is not costly. Buildings have got to be painted and decorated in some colour ; lamps and fittings have got to be purchased : they may as well be the right ones, and be arranged for a clearly defined rational use. In the next decade we may expect to see some very marked improvements in industrial buildings of all kinds, and it will be all to the good if the workers show their preference for places in which they are considered, by giving better service in such environments than where they are not considered at all. We have to turn our knowledge of the science and art of light and colour to some definite human use.

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[1] It might be worth the while of some of our factory psychological experts to compile data, from well-devised questionnaires, concerning some of the apparently trivial likes and dislikes, which affect the course of the industrial worker's life. Taking the very ordinary occurrence of a man voluntarily leaving a job, it is highly probable that a vastly larger number of reasons would be given, if the question is truthfully and willingly answered, than would be generally expected. It will be found that unpleasant surroundings, noise, wrong hours, lack of feeding accommodation, bad transit facilities, as well as personal dislikes of other members of staff, play more important parts than is realised.—W.G.R.

THE THIRST OF MAN

By ANDRÉ L. SIMON

Only the dead know no thirst! The living must breathe and drink to live. Morning dew and evening mists mean life to thirsty trees and parched green. Birds and beasts also are thirsty, and so is man! But the thirst of man differs from the thirst of clover or the thirst of ducks: the thirst of man is not the thirst of plants or animals for dew, rain, or river; it is the thirst of a living soul within a living body, a thirst that no running water was ever meant to quench, a thirst that ever did crave for water with a soul within, the mysterious soul we call alcohol.

The thirst of man is of very great antiquity: it is a truly noble thirst. The earliest records of the human race are records of the thirst of man, of man's efforts to secure, at a considerable cost in time, trouble, and money, the living blood of the grape—*Wine*—or else some substitute for wine.

The Vine.—The vine has flourished upon earth far longer than the human race. Long before the world we live in had become habitable, vines grew wild from pole to pole wherever land emerged from the great mass of waters which had not yet cooled down into oceans and seas. Fossilised vine-leaves and tendrils, identical in shape and size, have been found in Iceland, Alaska, Wyoming, Japan, and different parts of England, France, and Central Europe, in palæozoic and tertiary strata. From the beginning of the tertiary period, a considerable number of specimens found in the whole of the northern hemisphere, in Europe, America, and Asia, show the gradual evolution of the wild vine type towards the *Vitis vinifera* species.

In finds dating back to the Neolithic Period, or Stone Age, vine leaves and bunches of grapes are nearly always present among human remains. In the grottoes and *pfahlbauten* of Switzerland and Northern Italy, corn and grapes have been found which date back to the prehistoric lake-dwelling period, and, unlike the seeds of other fruit which have been identified and were always found singly or scattered about, grape-pips have usually been found in a compact mass, making it practically certain that the grapes from which they came had been gathered and pressed together in order to extract their luscious juice for the making of wine.

Mythology.—Wine among the Ancients was not only offered to the gods at most sacrifices, but it was given a place among the gods themselves: just as beauty, majesty, courage, and wisdom were worshipped under the names of Venus, Jupiter, Mars, and Juno, the life-giving grape, the elixir of eternal youth, the drink of the gods, *Wine*, was worshipped under the names of Bacchus in Roman days, and Dionysos in Greece and Asia Minor.

The worship of Bacchus is proof of the universality and antiquity of the love of wine and of the general use of wine, as well as of the gratitude of man towards the particular deity who had, it was believed, brought upon earth from Olympus the divine gift of the grape.

The worship of the wine deity originated in Asia, among the Aryans, and it spread wherever the Aryans migrated. In Persia and Armenia, as well as in Thrace, along the valley of the Danube and the whole of the Mediterranean seaboard, the Aryans found vines growing wild, and taught the natives how to tend them and how to make wine. Hence the similarity which exists to this day between the names given to wine among all nations. From *Vona*, the Sanscrit name of wine the Greeks made *οἶνος*, the Romans *vinum*, and it is still *wine*, *Wein*, *vin*, *vino*, *vinho* in English, German, French, Italian, Spanish, and Portuguese; *Gvino* in Georgian, *Gwini* in Mingrelian, *Ghini* in Armenian, *Gvinal* in Svan, *Wain* in Ethiopic, *Gwinien* in Celtic, etc.

The worship of Bacchus and the older deities of Greece, Persia, and Egypt, who were Bacchus's predecessors, was always greatly popular. The goat was the animal offered in sacrifice to Bacchus: the reason why being that one goat of old had dared nibble the tender shoots of a vine, a horrible crime indeed, the memory of which lives to this day, not in the mind of forgetful man, but in the very word *tragedy*, a word which means "the song of the goat," and was originally intended to remind us of the "tragic" misdeed of the vine-eating goat.

Ancient China.—The Chinese believe themselves to be the most ancient people on earth, and they are certainly entitled to the claim of a very early civilisation, since we read in their ancient records that Confucius, whose death is usually fixed at 478 B.C., wore a night-dress half as long again as himself—a state of refinement unknown in England two thousand years later, when even kings and queens knew not such luxury as a night-dress.

Both Confucius and the great philosopher Mencius, who died 288 B.C., have left many original precepts in which the temperate use of wine is commended and excess deprecated. They are also believed to have edited and perfected a series of books which had been handed down from generation to generation long before their time. In these books we find unmistakable proofs of the fact that from the earliest times the vine was cultivated on a very large scale and wine was commonly used, and not uncommonly abused, by many throughout the land. What is known as "The Announcement about Drunkenness," an imperial edict believed to have been promulgated about 1116 B.C., is particularly illuminating in this respect: it denounces both the use and abuse of spirits as the cause of drunkenness, and shows the art of distillation to have been practised for well over twelve centuries before Christ.

The Old Testament.—If both the Aryan and Turanian groups of the human race loved wine, so did the Semitic family. It is impossible to read the Old Testament without realising how important was the place held by the grape in the daily life and the ideals of the Hebrews of old.

Wine is not mentioned casually in the Bible, but a number of different types of wine are specifically described as follows: *Yayin, Schechar, Tirosh, Ahsis, Khemar, Khometz, Messech, Shevahrim.*

Yayin is the wine Melchisedech offered to Abraham, as did Jacob to Isaac and Naomi to the king. Whenever wine and bread are mentioned together as meaning food and drink, *Yayin* is the name used. "And they asked their mother, saying, 'Where is the corn and the wine [*Yayin*]?'" (Lam. ii. 12).

Yayin is the wine which "rejoices the heart of man": "The men of Ephraim will be like valiant soldiers, and will be glad at heart, like a man who has drunk wine [*Yayin*]" (Zech. x. 7).

Tirosh, which we find thirty-eight times in Holy Writ, has been translated both as "wine" and "new wine." In the majority of cases *Tirosh* is used to mean wine, when wine is mentioned at the same time as corn and oil. Corn, wine, and oil are repeatedly referred to in the Bible as the three staple foods necessary to the well-being of mankind—a verdict which has been endorsed in our own days by scientists who tell us that we want proteins (bread) for tissue building, and to make good the waste of albumen; carbohydrates and vitamins (*wine*) to supply the necessary dynamic power and make good the loss of bodily heat; and fats (oil) to build up and refill an indispensable store of caloric reserve. "Barns shall be filled with corn, and presses overflow with wine [*Tirosh*] and oil" (Joel ii. 24).

Scheehar, which is to be found twenty-three times in Holy

Writ, was used when wine was referred to as being inebriating. Thus: "Give them 'wine that is inebriating' [*Schechar*] who are in affliction, and give wine [*Yayin*] to them whose heart is sad. Let them drink and forget their misery and lose for ever the memory of their sorrows" (Prov. xxi. 6, 7).

Khemer, or *Khamar*, appears to have been a more poetical name for wine or to have meant a "purer wine" than the ordinary beverage wine. "Then the vine that shall yield the purer wine [*Khemer*] shall sing the praises of the Lord" (Isaiah xxvii. 2).

Ahsis refers to an aromatised wine, an early form of Hippocras. "I shall come for thee and lead thee into my mother's house: there thou shalt taste of a drink of wine mixed with aromats [*Ahsis*]" (Cant. viii. 2).

Soveh and *Mimsach* are used only five times in the Bible, and it is not quite clear to what sort of wines they refer.

Khometz meant a poor or sour wine, and sometimes vinegar.

Messech referred to a blend of wine and something else, or of different wines.

Shevahrim meant wine-lees, or wine with its lees.

Many learned commentators of Holy Writ believe that Mount Ararat, in Armenia, was the place where Noah landed after the Flood, and where he first planted a vineyard. There can be no doubt but that Armenia was from a very early date the home of flourishing vineyards. Some interesting discoveries have been made of late years at Ibriz, near Eregli, which have thrown much light upon the early civilisation of the Hittites, or Heteans, who flourished in Asia Minor fifteen centuries before Christ. One of the most important finds at Ibriz is a huge bas-relief over 18 feet in height, representing a bountiful god dispensing bread and wine; in his left hand he carries a tall sheaf of wheat, and in his right hand he holds a vine laden with huge bunches of grapes.

Egypt.—If we wish to study the past from records of stone and from the graves of kings, we must go to Egypt, and there we shall find abundant proofs of the love of man for wine and strong drink three and four thousand years before Christ.

The Egyptians always laid their more illustrious dead to rest in sumptuous chambers, with everything handy that they had enjoyed during their life upon earth, including food and drink, cups, etc. In many of these royal tombs, dating back to the XVIIIth dynasty, and even earlier, amphoræ have been found which showed unmistakable traces of having contained wine and honey. In practically all cases, carvings, drawings, and writings have been found also which, being deciphered, have revealed to us in the clearest possible fashion how important a place strong drink in general and wine in particular held in the laws, customs, and daily life of the whole population.

Mr. Loret, one of the most learned of Egyptologists, has deciphered ten different varieties of wine which were popular in Egypt at the time of the erection of the Pyramids. They are rendered as follows:

"White wine; red wine; superior wine; second wine; syenite wine; northern wine; midland wine; Tokhnes wine; Neha wine; Sekhi wine."

The Egyptians brewed ale, and made a number of alcoholic beverages by blending different wines together and adding honey and herbs.

Honey.—There is every reason to believe that from the earliest times men added honey to thin and acid wines because they found them more agreeable when so sweetened. In some cases, if given sufficient time and air, honeyed wine would go on fermenting longer and become stronger: this must have induced men to use honey with all sorts of bitter and acid berries in order to obtain some alcoholic beverages wherever the vintage happened to be a failure, or wherever, as was the case in Northern Europe, climatic conditions made the cultivation of grapes, if not impossible, at any rate unprofitable.

POPULAR SCIENCE

THE NORMAN BRIDGE LABORATORY OF PHYSICS, ITS EQUIPMENT AND WORK

By E. C. WATSON,

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General Description

The Norman Bridge Laboratory of Physics, which houses the research and instructional work in physics carried on at the California Institute of Technology, Pasadena, California, consists of two units of five floors each, 128 by 58 feet, connected at the north by a third unit of two floors 80 by 52 feet, so as to form three sides of a hollow square. One of these units has in addition a special photographic laboratory on a partial sixth floor, and each has on its large flat roof excellent facilities for outdoor experimentation. The four upper floors of the first two units are above ground and well lighted by outside light ; the lowest floor, or sub-basement, is completely below the ground-level, but is perfectly dry and provides a number of large constant-temperature rooms which are unusually free from surface noises and ordinary vibrations. The first of the three units was erected in 1920 and 1921, and the last in 1923 and 1924. The building was made possible through the generosity of Dr. Norman Bridge of Los Angeles, who has given more than £110,000 for this purpose.

The first unit contains a lecture-room seating 260 persons, with a commodious apparatus-room immediately adjoining it, two large undergraduate laboratories with adjoining dark-rooms and apparatus-rooms, three class-rooms, three laboratories for advanced instruction, nine offices, a store-room, a chemical room, the graduate library of physics, and twelve research-rooms, besides the shops, and the machinery, switch-board, and storage-battery rooms.

The second unit is used primarily for research. It contains forty-five research-rooms as well as a seminar-room, photographic dark-rooms, a chemical room, fourteen offices, and switch-board, storage-battery, electric-furnace, and machinery rooms.

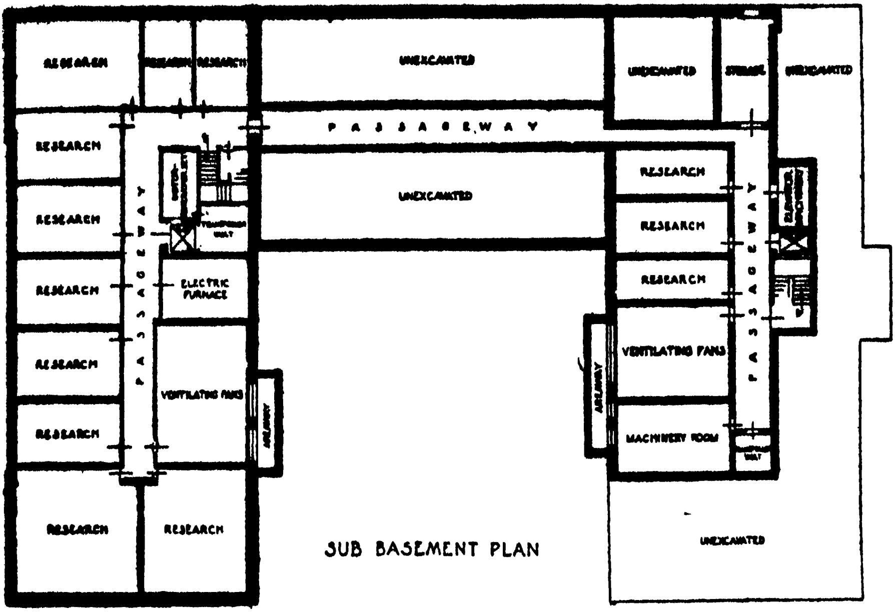
The third-unit houses on one floor eight more research-rooms, thus bringing the number of rooms devoted exclusively to research up to sixty-five, and on the other the Norman Bridge

Library of Physics, to provide for which Dr. Bridge generously gave a further £10,000.

The building is of the reinforced concrete skeleton type, the columns, outside walls, and floor slabs carrying the entire weight and providing almost the entire strength of the building. Interior partitions are of hollow tile, and (except corridor walls) have been kept almost free from permanent wiring or piping; so that rooms may easily be made larger or smaller by removing or inserting a wall. A unit of about 16 by 22 feet has been adopted as the most useful size, and nearly all rooms are either this size or multiples of this size. The general arrangement of the rooms will be evident from an inspection of the accompanying floor plans (Figs. 1–6).

Each unit of the building is provided with a freight elevator designed to carry 2,500 pounds. Provision is made in each unit, by means of a removable slab in each floor, to provide at some future time a vertical shaft extending from the roof to the sub-basement. Moreover, a large number of eight-inch holes (with steel covers) through the floor slabs connect each room with those above and below. An horizontal duct along the ceiling of the basement and sub-basement halls deep enough for a man to crawl through and a number of vertical shafts enable new wiring and plumbing to be installed in any room in the building without cutting the plaster or concrete. Floor trenches with removable steel covers connecting with these ducts and shafts permit wires and pipes to be led to any point in any room at any time. On all four sides of practically every room apparatus strips have been installed at three feet and six feet from the floor, and all rooms have heavy picture moulding designed to carry heavy loads. In order to make it possible to suspend apparatus from the ceiling at any point, wooden strips were fastened during the construction of the building along the forms in approximately the neutral axis of the beams, so that, after the concrete had been poured and the forms removed, there was left a slot into which a two-by-four strip of appropriate length can be wedged. Fig. 7 is a photograph of the ceiling of one of the rooms showing these slots running along each beam and the wooden strips, from which apparatus is hung, extending across from one beam to the next. All windows are framed in such a way that, when lightproof curtains are provided, the room may be completely darkened, the curtains being held tightly against the flat frames by folding strips of wood.

A serious attempt has been made to combine real architectural beauty with general utility, and great credit is due to the architect, the late Bertram G. Goodhue of New York City, for the high degree of success attained. The architectural beauty of the building does contribute in a large way to the " mental


RESEARCH
RESEARCH
RESEARCH
UNEXCAVATED
UNEXCAVATED
STORAGE
UNEXCAVATED
PASSAGEWAY
RESEARCH
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RESEARCH
RESEARCH
RESEARCH
RESEARCH
PASSAGEWAY
ELECTRIC FURNACE
VENTILATING FANS
AREAWAY
UNEXCAVATED
RESEARCH
RESEARCH
RESEARCH
VENTILATING FANS
MACHINERY ROOM
AREAWAY
PASSAGEWAY
UNEXCAVATED
SUB BASEMENT PLAN

FIG. 1.

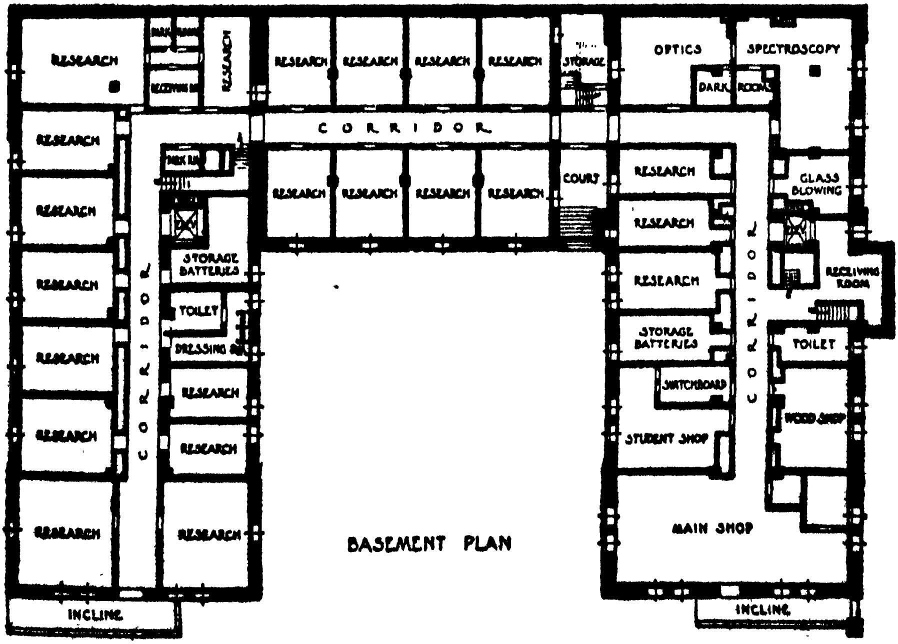
RESEARCH
DARK ROOM
RECEIVING RM
RESEARCH
RESEARCH
RESEARCH
RESEARCH
RESEARCH
STORAGE
OPTICS
SPECTROSCOPY
DARK ROOMS
CORRIDOR
RESEARCH
RESEARCH
RESEARCH
RESEARCH
RESEARCH
RESEARCH
CORRIDOR
STORAGE BATTERIES
TOILET
DRESSING RM
RESEARCH
RESEARCH
RESEARCH
RESEARCH
RESEARCH
RESEARCH
RESEARCH
COURT
RESEARCH
RESEARCH
RESEARCH
STORAGE BATTERIES
SWITCHBOARD
STUDENT SHOP
CORRIDOR
GLASS BLOWING
RECEIVING ROOM
TOILET
WOOD SHOP
MAIN SHOP
BASEMENT PLAN
INCLINE
INCLINE

FIG. 2.

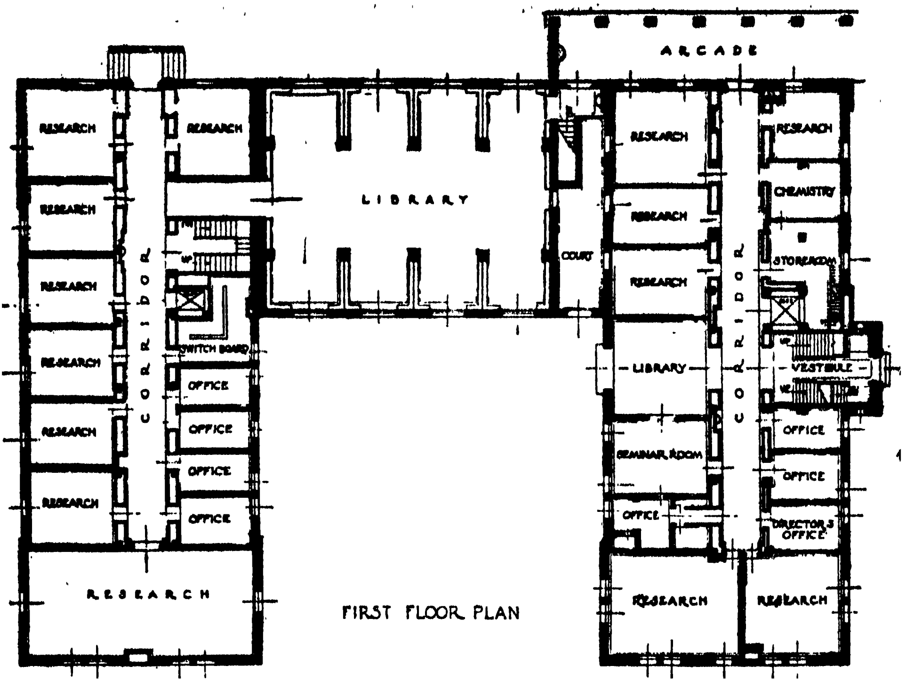
ARCADE
RESEARCH
RESEARCH
LIBRARY
COURT
RESEARCH
RESEARCH
RESEARCH
CHEMISTRY
RESEARCH
STOREROOM
RESEARCH
CORRIDOR
RESEARCH
SWITCH BOARD
LIBRARY
VESTIBULE
RESEARCH
OFFICE
CORRIDOR
RESEARCH
OFFICE
SEMINAR ROOM
OFFICE
RESEARCH
OFFICE
OFFICE
OFFICE
OFFICE
DIRECTOR'S OFFICE
RESEARCH
RESEARCH
RESEARCH
FIRST FLOOR PLAN

FIG. 3.

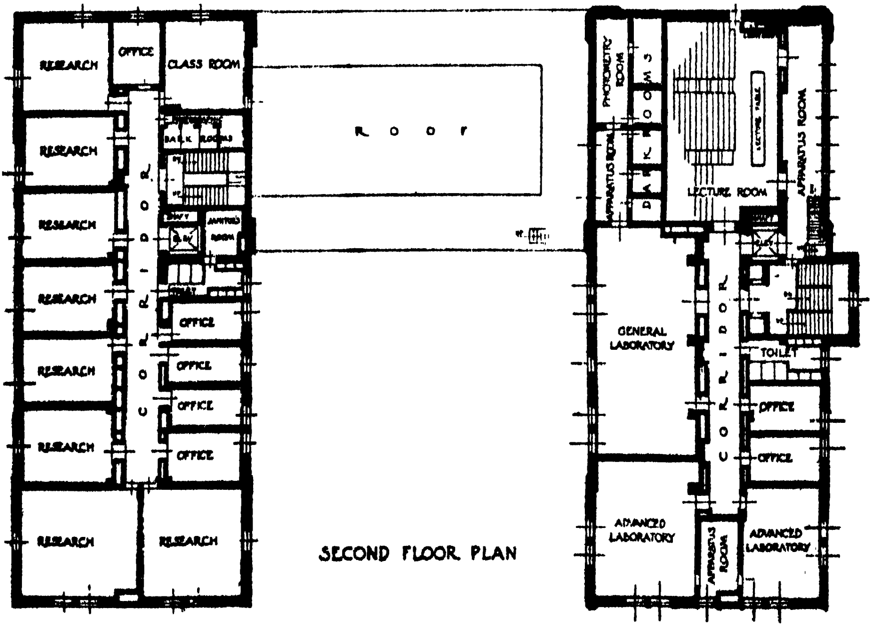
RESEARCH
OFFICE
CLASS ROOM
PHOTOMETRY ROOM
DARK ROOMS
LECTURE TABLE
APPARATUS ROOM
ROOF
RESEARCH
APPARATUS ROOM
LECTURE ROOM
RESEARCH
CORRIDOR
RESEARCH
JANITOR'S ROOM
GENERAL LABORATORY
CORRIDOR
RESEARCH
OFFICE
TOILET
RESEARCH
OFFICE
OFFICE
OFFICE
RESEARCH
OFFICE
OFFICE
ADVANCED LABORATORY
APPARATUS ROOM
ADVANCED LABORATORY
RESEARCH
RESEARCH
SECOND FLOOR PLAN

FIG. 4.

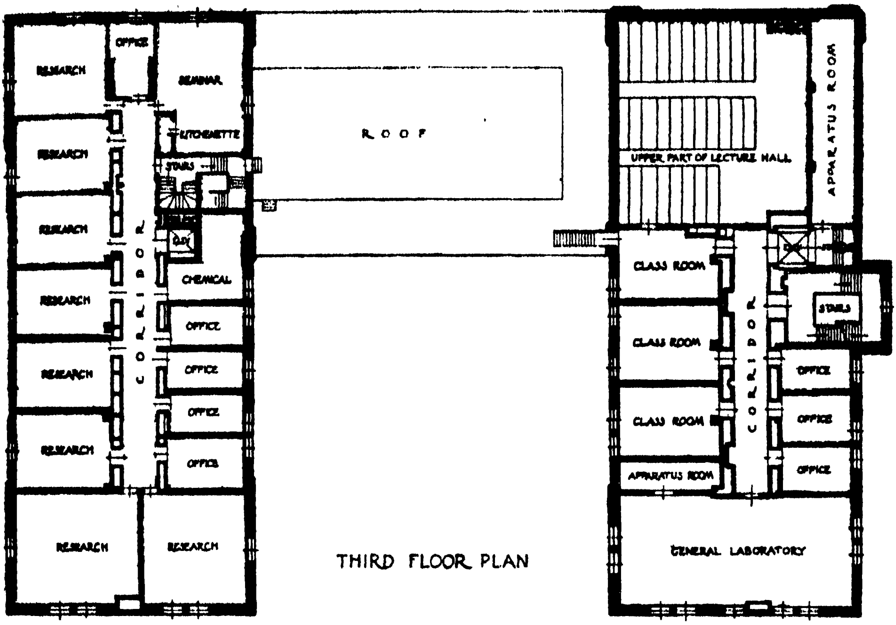
RESEARCH
OFFICE
SEMINAR
KITCHENETTE
STAIRS
RESEARCH
RESEARCH
RESEARCH
RESEARCH
RESEARCH
CORRIDOR
CHEMICAL
OFFICE
OFFICE
OFFICE
OFFICE
RESEARCH
RESEARCH
ROOF
UPPER PART OF LECTURE HALL
APPARATUS ROOM
CLASS ROOM
CLASS ROOM
CLASS ROOM
APPARATUS ROOM
STAIRS
CORRIDOR
OFFICE
OFFICE
OFFICE
GENERAL LABORATORY
THIRD FLOOR PLAN

Fig. 5.

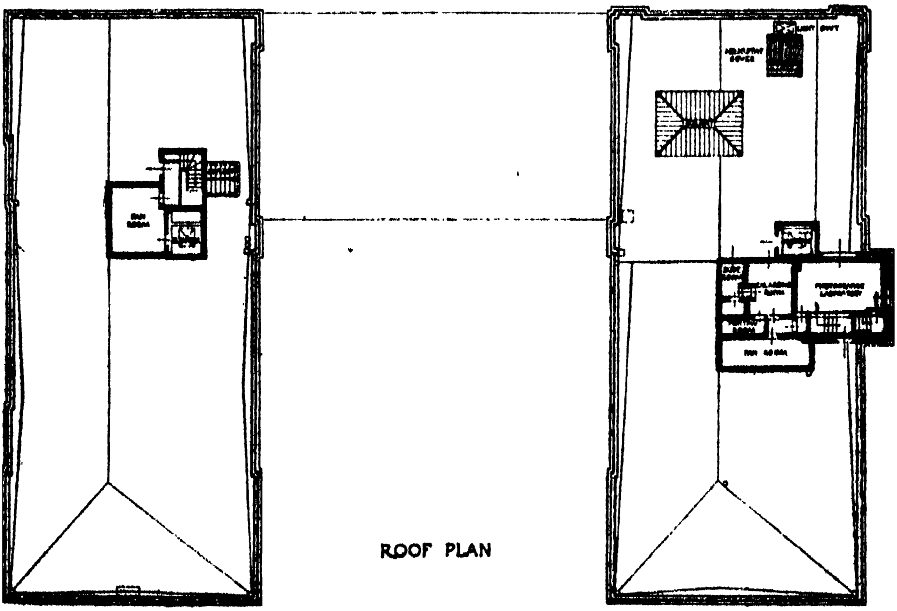
FAN ROOM
ROOF PLAN

Fig. 6.

health, power, and pleasure " of those working in it, and should be a large factor in creating the proper atmosphere for real creative work such as it is hoped the laboratory will foster.

The building is in the style of the Spanish renaissance of the rococo period, somewhat more refined in detail, however, than most of the work of that particular period. This style of architecture greatly influenced most of the Spanish-colonial work in Mexico and characterised the work put into the California Missions so far as those early builders in Southern California were able to interpret it and carry it out. It is natural, therefore, that this style should influence the design of many important architectural works in Southern California, such as the Norman Bridge Laboratory of Physics. Among the prominent exterior features are the massive pylons, hand-towelled walls, extensive art stone panels with diaper pattern, and heavy wrought-iron window grilles (Fig. 8). Inside are noted such details as the heavy grilled library door (Fig. 9), wrought-iron stair rails, vaulted ceilings, and red-tiled floors (Fig. 10). Niches in the thick walls of the corridors (Fig. 10) provide places for striking scientific exhibits or works of art. A ceiling ornament in the library and the ornamentation of the circular panels between the window spaces on the exterior of the first unit (Figs. 8 and 11) are cryptic symbols representing the four physical elements as they were known to the ancients —earth, water, fire, and air. Similar panels on the second unit symbolise modern science (Fig. 12), and represent in one circle the Compton effect and in the other the model of the carbon atom thought most probable at the time the unit was built. (These would serve to date the building very accurately, as the model of the carbon atom is probably already superseded.)

THE EQUIPMENT OF THE LABORATORY

Shops.—Probably the most important feature of the laboratory is the shop. Four full-time mechanicians and a glass-blower are employed to aid the research men in the design and construction of research apparatus. The laboratory is particularly fortunate in having such men as Mr. Julius Pearson, Head Instrument Maker, and Mr. William Clancy, Glass-blower; for much of the research work of the laboratory would be impossible were it not for their intelligence, skill, and experience. They are not only extraordinarily skilful workmen, but their judgment and advice in the construction of all sorts of research apparatus is indispensable.

The main shop, a room 24 by 52 feet, is equipped with two eight-inch Rivett back-geared, precision lathes complete, one eight-inch Rivett plane precision bench lathe, a Pratt and Whitney eight-inch tool-maker's lathe, two sixteen-inch lathes, a Brown and Sharpe milling machine, a fourteen-inch shaper, a power saw, a twenty-inch heavy duty drill-press, a sensitive drill-press, an electric welder, an emery grinder, a small gas forge, and an electric oven, as well as a large number of small tools and stock. The whole floor of this shop is floated on sand free from the rest of the building, and the machines are driven from overhead shafting by independent motors mounted on a steel framework supported from the floor. Little vibration is communicated to the rest of the building.

The glass-blower's shop has various blow-torches for glass and quartz, and machines for grinding and polishing, as well as a complete high vacuum system of mercury diffusion pumps capable of producing the highest vacuum. Furnaces for baking out vacuum apparatus while pumping are also available, as well as high potential direct current for electron bombardment of metal parts. An adequate stock of stop-cocks, soda, lead, pyrex, and quartz glass tubing and bulbs is maintained at all times. However, pyrex and quartz are used almost exclusively.

Members of the laboratory do not, except in special cases with the permission of the mechanicians in charge, use the above shops. They may, however, make free use of the research students' shop, which is equipped with a bench screw-cutting lathe, an engine lathe, an emery grinder, a bench drill-press, vises, pipe-fitting and cutting tools, soldering-irons and torches, and a goodly number of hand-tools. They also make free use of the carpenter's shop, which is equipped with a band-saw, a combination buzz saw and planer, and a wood-turning lathe, as well as the necessary hand-tools. An adequate supply of lumber and metal stock is maintained at all times.

The liquid air plant consists of a twenty-horse-power, four-stage, Norwalk compressor, and two sets of purifying tanks, and two liquefiers ; so that is is not necessary to shut down to make repairs or to change chemicals. All but the compressor were constructed in the laboratory. The output is over two litres an hour.

Wiring and Plumbing.—Probably the most elaborate single item is the electrical wiring. In each room is installed a switchboard of Johns Manville ebony asbestos wood with two three-pole and two two-pole sixty ampere switches from which connection can be made either directly to apparatus or to various wall outlets, usually at least three in number conveniently placed around the room. Four wires lead from each of these outlets to the switchboard, thus allowing either two two-wire circuits to be used or one three-wire circuit. In addition to these outlets several A.C. power outlets are provided in each room.

From the laboratory switchboards ten No. 8 conductors lead to a row of jacks on the main distributing switchboard. By means of fused jumpers any of these jacks can be connected with any sort of electric power desired. A.C. power and D.C. generator service are obtained from buses mounted vertically on the rear of each panel. These buses consist of nine three-quarter-inch square brass bars mounted between the ten vertical rows of outgoing jacks. The first three are connected to the generators on a three-wire 110–220 volt circuit, the middle three through a circuit-breaker to 110 volt three-phase A.C. power, and the last three through a circuit-breaker to 220 volt three-phase A.C. power, so that either 110 or 220 A.C. power single-phase or three-phase can be obtained. Current from the storage batteries at any voltage from 2 to 500 volts in 2 volt steps can be obtained by plugging to the storage battery panel.

Only A.C. power is received from the outside. D.C. is obtained from a fifty kilowatt three unit motor-generator set equipped with a voltage regulator to maintain the voltage constant at 110–220 volts, from a variable voltage fifteen kilowatt three unit motor-generator set, from a five and a half kilowatt battery charging motor-generator set, and from two two-hundred ampere-hour storage batteries of 125 cells each. Provision has also been made for installing 125 more cells at a later date. The batteries are arranged in groups of ten cells each, with No. 2 wires attached to the ends of each group and No. 10 wires to intermediate points. This permits thirty ampere circuits in steps of two volts and high capacity circuits in steps of twenty volts. Series switches connect all ten cell groups together. A large number of portable storage batteries are also available for low voltage demands.

In all, thirty-eight feet of switchboard are required to distribute power to all the rooms in the building. All wiring is carried in the horizontal ducts, vertical shafts, and floor trenches already referred to, and so is readily accessible at all times. It is interesting to note, in this connection, that all of the wiring and electrical equipment of the building have been installed by students of the Electrical Engineering Department of the Institute.

Each room is supplied with gas and compressed air, and both water and waste pipes are available in every room. Capped water, gas, and air outlets, as well as drains, are provided at convenient places in the pipe and wire shafts and in the floor trenches for future extension of the system, and to enable gas, water, or air to be brought out to tables in the middle of the rooms. Gas, air, water, and electrical outlets are also provided on the roof to facilitate outdoor experimental work.

Lecture-hall.—The lecture-hall is a room 44 feet square and two stories high to admit of elevating the seats so that the lecture-table may be plainly visible from any point in the room. It receives outside light only through a skylight, and can be darkened quickly, easily, and completely by means of motor operated curtains. This mechanism is unique and probably worthy of further description. The curtains are suspended on slide wires, and are opened and closed by a continuous cable making a couple of turns around a drum. This drum is driven through a worm by a three-phase motor. Reversal of the motor is accomplished by a four-way tumbler switch which is operated by limit stops attached to the cable. Connected with this switch operating mechanism is also a controlling switch. This is simply a three-way tumbler switch which is connected with other three-way and four-way switches located in the lecture-room, one on the lecture-table and the other in the rear of the room on the lantern-stand. These switches control the operating coil on a three-pole remote control magnetic switch in the motor circuit. Three- and four-way switches operating a remote control on the electric lights of the room are found at each end of the lecture-table, beside the entrance of the room, in the rear of the room on the lantern-stand, and at the end of a cord which can be carried about by the lecturer.

An I-beam, mounted in the ceiling above the lecture-table and extending the entire width of the room, carries a small crane and makes possible the easy handling of heavy apparatus for demonstration purposes. A special and unique feature is a lantern-screen carried on the same I-beam and easily adjustable as to angle and height to facilitate projection vertically, or otherwise, from any part of the room. A trap-door in the ceiling over the lecture-table, opening into an attic room, further facilitates hanging from the ceiling and makes possible experiments on falling bodies and the like. A light shaft in one corner of the room and in line with the lecture-table enables sunlight to be obtained throughout the day from a cœlostat upon the roof. A similar shaft in the opposite corner of the room enables new wiring and plumbing to be installed in the lecture-table at short notice. The ceiling of the room is covered with special felt panels to deaden reverberations. The usual electrical connections, water, gas, and compressed air, as well as the usual lecture-room appurtenances, are, of course, available.

Apparatus-rooms.—Apparatus and supplies are distributed from a central store-room. Apparatus, when not in use, is kept in specially constructed dust-proof cases in the apparatus-rooms adjoining the various laboratories or in the commodious three-floor apparatus-room which opens off the lecture-hall. The elevator stops at each floor of this apparatus-room and a stair leads from it to the general store-room.

Spectroscopic Equipment.—In addition to the usual equipment of an optical laboratory, a specially designed twenty-foot-focus plane grating spectrograph of the two-lens type, and a twenty-one-foot focus Rowland concave grating spectrograph are being provided in the spectroscopic laboratory. In order to conserve space and obtain greater stability and constancy of temperature these instruments are mounted in a vertical position with lenses and gratings in a constant-temperature pit beneath the floor. Sunlight for this floor, for the lecture-hall, and for various purposes at other floors can be obtained at all times throughout the day from a cœlostat upon the roof through an open light shaft extending from the roof to the tub-basement.

Photographic Laboratories.—A number of individual dark-rooms have been provided as well as a photographic laboratory equipped with the usual cameras and auxiliary outfit for copying, enlarging, and making lantern-slides. Either artificial or natural light is available for this work.

High Vacuum Equipment.—A general vacuum system was not installed in the building, but each research which requires a high vacuum is provided with a motor-driven Central Scientific Company Hyvac pump, and a two-stage mercury vapour diffusion pump of pyrex glass designed and built in the laboratory. At the present time more than thirty such outfits are in use.

Seminar-room.—The seminar-room is arranged for small discussion groups around a central table. It will accommodate from fifty to sixty people without losing the congenial atmosphere of the small seminar. A kitchenette adjoining it, equipped with sink, gas, and electrical heating appliances, and cupboards, makes it possible to serve tea and wafers before or during the seminars.

Ventilations.—The building is under forced ventilation. The air comes in directly from outdoors and is washed, as well as heated or cooled, as occasion may require. Under normal conditions the air in each room is completely changed every five minutes. All this is under thermostatic control. The ventilating machinery, as well as all other heavy machines in the building, is mounted on a cork base and the floor supporting it is floated on sand free from the rest of the building.

Miscellaneous Equipment.—A bath and locker room equipped with two showers is provided for the use of the research men and staff who desire to play tennis or take other forms of exercise during the day. There are in the building two chemical rooms stocked with acids and the more common chemicals and equipped with chemical hoods and desks.

The Work of the Laboratory

In addition to the theoretical work being done by Drs. Bateman, Epstein, and Tolman and their students, there are at the present time more than forty independent experimental researches under way in the laboratory, carried on by some forty-five different men, consisting of graduate students,

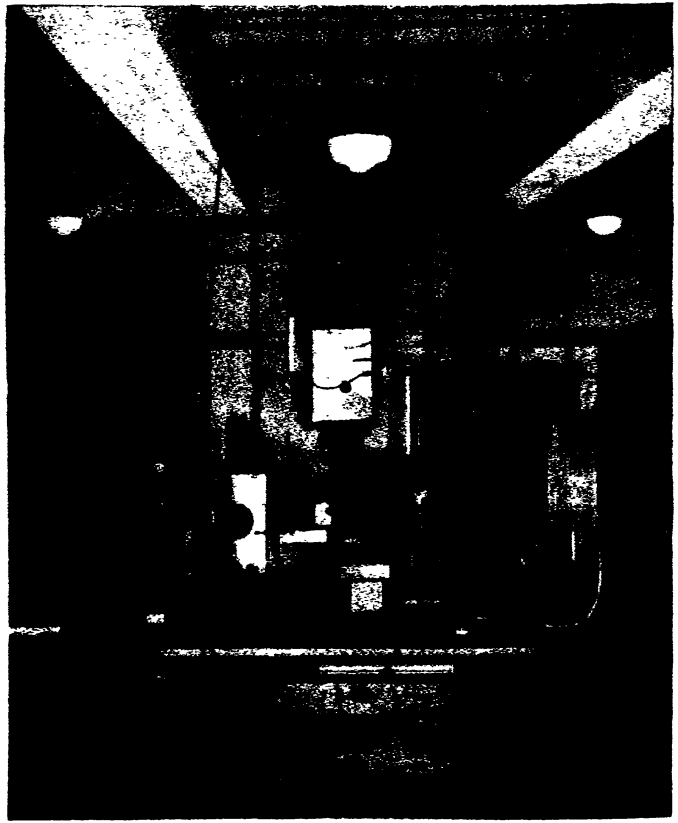

Fig. 7.

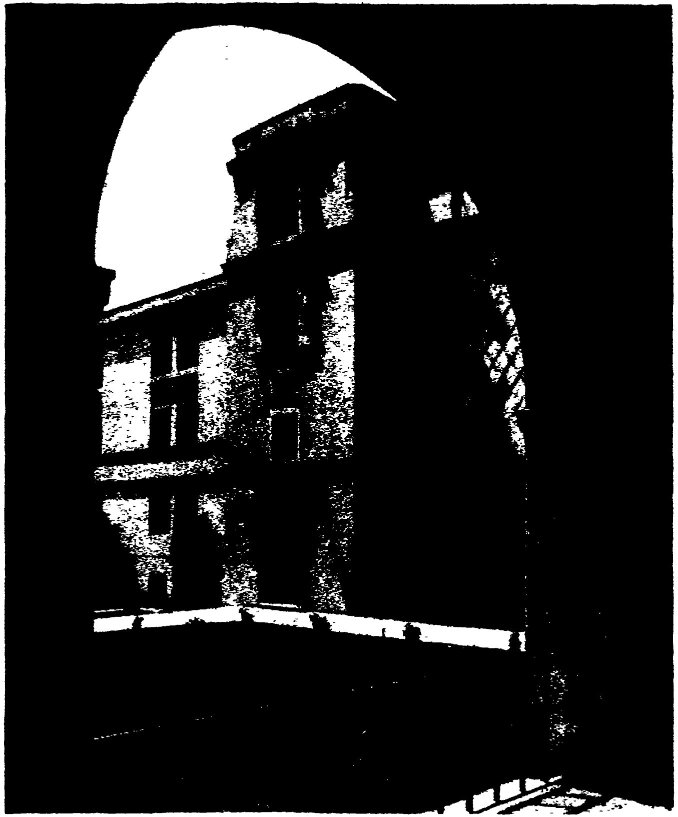

Fig. 8.

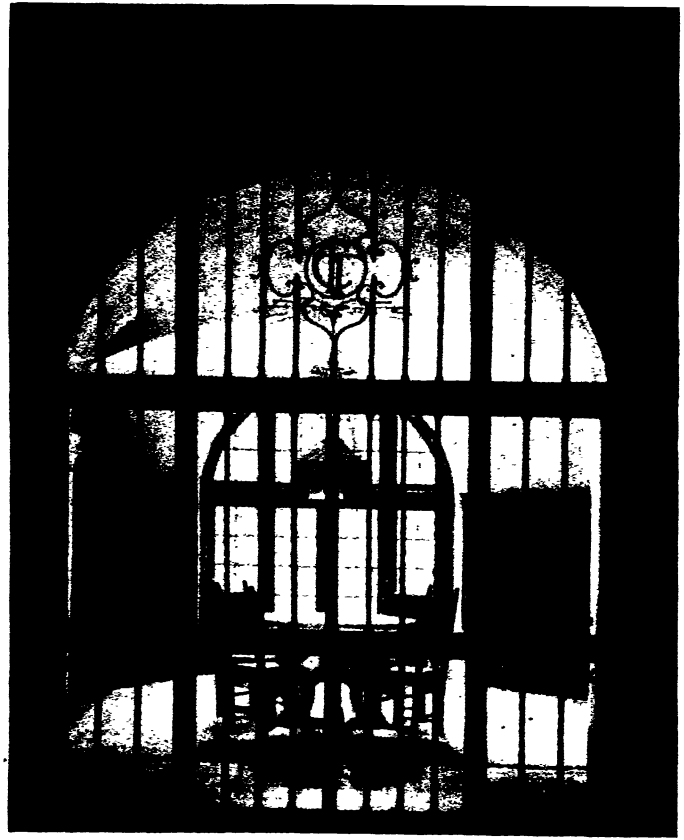

Fig. 9.

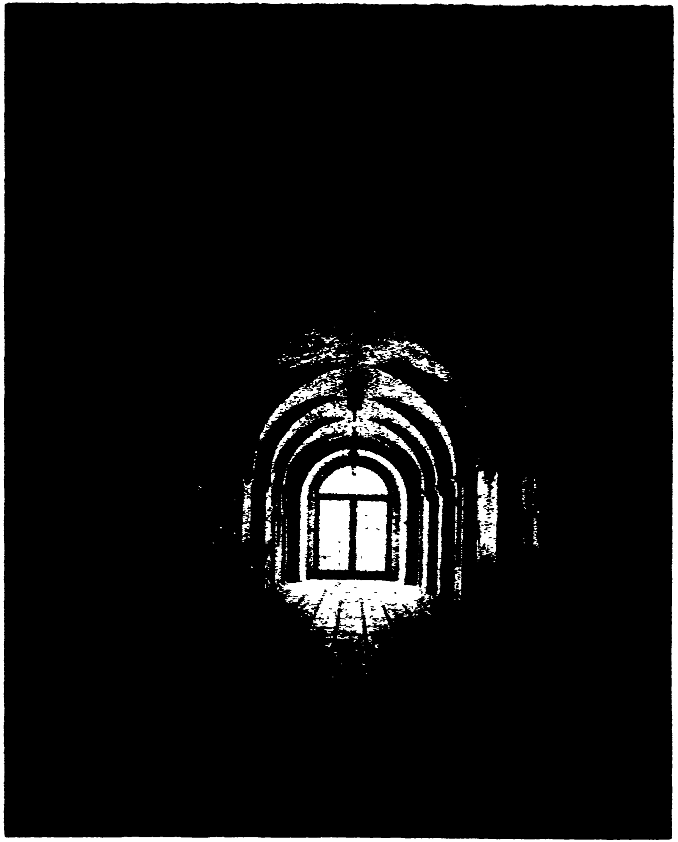

Fig. 10.

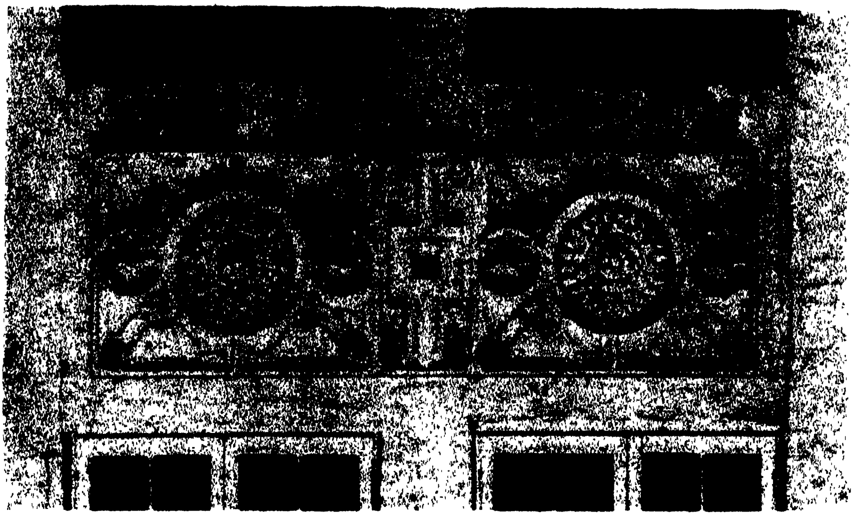

FIG. 11.

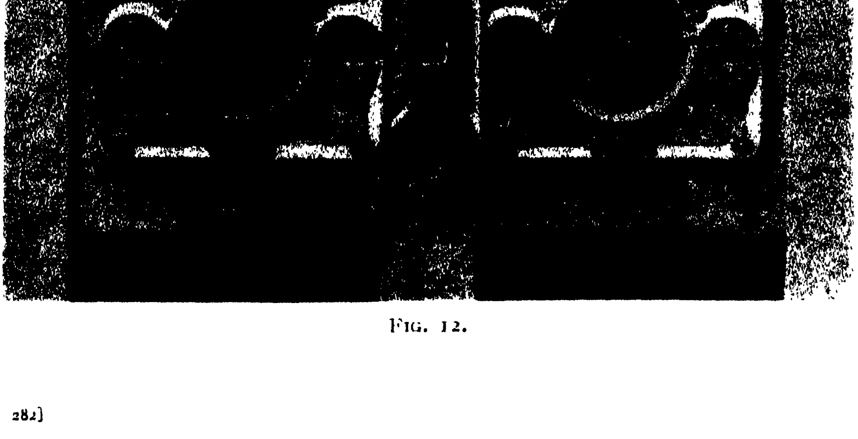

FIG. 12.

members of the staff, and guests from other institutions. Among the latter are, at the moment, Dr. S. J. Barnett, whom the Carnegie Institution of Washington assigned to the laboratory to continue there his important magnetic work; Dr. Stanislaw Loria, Professor of Physics at the John Casimir University, Lwow, Poland; Dr. Albert Björkeson, Assistant Professor of Physics at the University of Upsala, Sweden; Dr. Otto Oldenberg, of the University of Göttingen, Germany; Dr. Lars Thomassen, of the Mineralogical Institute, Oslo, Norway; Dr. Max Wehrli, of the University of Zürich, Switzerland; six National Research Fellows, namely: Dr. A. Keith Brewer, from the University of Wisconsin; Dr. Herbert Kahler, from Cornell University; Dr. Roy J. Kennedy, from Johns Hopkins University; Dr. Edward H. Kurth, from Princeton University; Dr. Stuart S. Mackeown, from Cornell University; and Dr. William R. Smythe, from the University of Chicago.

To list the forty researches being carried on by the advanced students, the fellows, and the regular staff would be rather tedious and not particularly illuminating; but the main fields of activity are the following: A very considerable group of spectroscopic problems are under way, quite a number of them being carried on with the aid of "hot spark" spectrometry developed by Dr. Millikan and Mr. Bowen. Several photoelectric experiments, and a whole group of experiments on the effect of minute surface impurities upon electrical and optical behaviour are being pursued. A group of experiments on the beta-ray analysis of hard and soft X-radiations, and another upon the effect of the impacts of both positive and negative rays in ionising both solids and gases, are yielding interesting results at the moment of writing. Another series of problems upon isotopes, and still another on the penetrating radiations of the upper air, are being actively followed. Still another group concerns the Compton and the C. T. R. Wilson effects. Band spectra are being actively studied in the ultra-violet region, the optical region, and the infra-red region. Seismological and earth-tide experiments are also in progress, as are many problems which make use of the million-volt, thousand-kilowatt transformer housed in the adjoining high-tension laboratory. Dr. Barnett supervises a group of magnetic problems, while Dr. Tolman is making elaborate studies of electrons in metals.

Nearly all the problems come under the general heading, "The Structure of Matter and the Nature of Radiation," the Carnegie Corporation of New York having appropriated funds for a joint attack upon this general problem by the Mount Wilson Observatory, the Gates Chemical Laboratory, and the Norman Bridge Laboratory of Physics.

June 30, 1925.

NOTES

Dr. Gye and Cancer (J. E. McCartney, M.D., D.Sc.)

The experiments were made with a sarcoma of the fowl, first described by Petyon Rous in 1911, which is peculiar inasmuch that it can be transmitted from chicken to chicken by inoculating dead cells, killed by drying or with 50 per cent. glycerin, or by the cell-free fluid obtained by passing an emulsion of the tumour in saline solution through a Berkefeld filter.

If a filtrate of the tumour is treated with chloroform it does not produce a tumour when injected into a chicken.

Further experiments showed that there are two factors concerned in the production of an experimental tumour. One is the virus of the tumour which belongs to the class of so-called "filterable viruses," and the other is a specific factor probably of a chemical nature and present in the tissue-cells. Neither of these two factors alone is capable of causing a tumour, but when combined a sarcoma results. The treatment of the tumour filtrate with chloroform kills the virus, but leaves the specific factor.

The virus itself can be cultivated from fresh filtrate (which contains both factors) under strict anaerobic conditions in potassium chloride broth, to which rabbit serum and a fragment of chick embryo have been added. In the fifth sub-culture the amount of specific factor carried over from the original filtrate must be exceedingly small, and the sub-cultures contain the virus only.

It is thus seen that the chloroform filtrate contains specific substance only, and the subculture only the virus. Neither by themselves cause a tumour, but a mixture of the two when injected into a chicken invariably produces a sarcoma.

Dr. Gye has shown that there is one virus for all malignant tumours, whether human, mouse, rat, or chicken, etc., but that the specific or chemical factor is distinct for each species of animal. Thus, the virus from a mouse tumour plus specific factor for the chicken will produce sarcoma in fowls only, but not in rats or mice. Similarly, human virus plus mouse specific factor together produce tumours only in mice and not in any other species of animal. Dr. Gye has thus shown that malignant disease is due to a multiplying infective agent common to all species, together with a chemical factor specific to the particular animal.

The Originators of Aviation and of Wireless

It is curious how many nations make claims regarding discoveries and inventions—justifiable or not. Recently M. Clément Ader died at the age of eighty-four at Toulouse, and the French claim for him that he was the originator of aviation. He constructed a flying machine in 1886, and next year a more perfect one, known as the *Avion*, which was said to have flown some three hundred yards in the presence of officials. It was, however, so imperfect that these officials turned down the invention, and M. Ader retired from further efforts; but he was made a Commander of the Legion of Honour before his death. Similarly, the late Prof. Alexander Popoff received posthumous honours in Russia on May 7 last, on the plea that he was the discoverer of wireless telegraphy, and *Science* says that the Kronstadt Electrical Academy has been named after him. The public take so little interest in the men who give them the very greatest benefits as regards scientific inventions that scarcely anyone knows even their names.

Modern Miracles

In June last we saw a film at the New Galleries, Regent Street, based upon Sir Arthur Conan Doyle's novel *The Lost World*; and we were amazed at the numerous miracles there shown. Many prehistoric animals were revived and moved, fed, and fought freely before the eyes of the audience. It was a wonderful sight to see a megalosaurus (we have forgotten its proper name) walking about in the streets of London, and the well-dressed or ill-dressed crowds fleeing before the monster. There was no doubt about the miracles, because everybody saw them—in fact, the alleged miracles by spiritualists in darkened rooms, and before the eyes of a few privileged guests, are absolutely nothing to those which we all beheld upon the film. If the former can easily be worked by clever people, so can the latter, and much more easily.

A New Kind of Maiden Speech

It is not often that maiden speeches in Parliament deal with such mean subjects as science and scientific institutions, but Mr. Tinne, the Member for Wavertree, manifested this weakness when he addressed the House for the first time on July 27—though he asked for the "indulgence which is usually given to a first offender." His speech, for which he received the congratulations of the Rt. Hon. Mr. Fisher, M.P., dealt chiefly with the Liverpool School of Tropical Medicine, of which he is Treasurer; and we hope that his remarks will help that valuable institution. How astonished Parliament must have been to hear that such trivialities as trypanosomiasis, ankylostomiasis, malaria, and other diseases destroy millions of our subjects throughout the world and affect many more millions, and that it should even spend a little money for the purpose of controlling these plagues. After all, such maladies, like those which affect us in Britain, are really of some importance. Whether a citizen should pay an extra shilling on his income-tax or not is doubtless a matter of considerable concern to him ; but we dare to maintain that whether he dies or not of some preventable disease is a matter of much greater concern. Yet this argument finds little illustration in Hansard. Perhaps a cynic might maintain, with some show of reason, that the British people have not yet developed sufficient intelligence to possess, or even to pretend to possess, any interest in the immense communal benefits which science and invention confer upon them. He might argue that, intellectually as physically, the mass of them remain in nearly the same condition as that of their forefathers of the Middle Ages. That they adore processions and ceremonies, kings and peers, soldiers marching past with flags and bands, full-dress "functions," cathedral services, and reviews. That their parliaments, after interminable and costly discussions, achieve only a small redistribution of wealth, of doubtful advantage to anyone; that their politicians are constantly engaged in pouring water from one set of buckets into another set of buckets ; and that the public watches them with fascination because it really believes that this is the way in which the total stock of water may be increased. The cynic will conclude that the masses are like children in the nursery, blowing tin trumpets or marshalling leaden soldiers, and then suddenly coming to blows and tears over their mimic wars—and it will be difficult to contradict him.

Scientific Periodicals

The Times of August 3 contained an interesting article on the publication of research, in which it is stated that, according to the first volume *A World List of Scientific Periodicals*, recently issued by the Oxford University Press, there were no fewer than 24,028 periodicals in existence from 1900 to 1921, which published the results of scientific research. We are astonished at this figure, and suppose that most of the publications are those of learned societies, or perhaps that the list includes any periodical which occasionally publishes something "in the scientific line." The writer of the article in *The Times* considers a scheme for the prompt, adequate, and complete indexing of all this literature, by the establishment of a central library containing all the periodicals. We may observe that the Royal Society was long engaged in making an index of scientific papers. On considering the matter as a whole, however, we are inclined to think that the vast bulk of this alleged scientific literature is almost worthless, or, if it be not worthless, it appeals only to specialists who are easily able to trace papers which concern them directly without troubling to " look up " the literature in such a public library. Most scientific articles are merely confirmatory of previous ones. Our experience suggests the following proportions, namely, that 5 per cent. of the published papers are valuable, that 90 per cent. of them are of no value, and that another 5 per cent. of them are spurious—that is, they are incorrect or describe work that has never really been done. Science is tending to smother itself with its own excessive output of worthless or bad work, and we fear that minute cataloguing of all this literature would only help to make confusion worse confounded. Time is the great clarifier; and, though good work is sometimes lost, bad work is more often excluded from remembrance by the oblivion which it deserves. What is really required is a limitation in the amount of trivial or spurious scientific literature.

On All-fours

In August last there was held an International Conference of Osteopaths at the Savoy Hotel in London, and, to judge from the reports in the lay press, some of the contributions must have been distinctly progressive—though, doubtless, the net results of the Conference might have been quite useful. One gentleman, who discussed diet, is said to have averred that cooking killed the life of food, and that in his regular programme of diet he did not include meat, milk, butter, cheese, eggs, salt, pepper, vinegar, or sugar. Nevertheless, he sometimes had thirty-nine articles of food on the table, consisting of nuts, cereals, honey, sweet fruits, and lemon-juice. Potatoes should be eaten absolutely in their natural state without boiling, baking or other preparation. He had followed this dieting for four years, and was ten years younger. After uncooked food his heart-beat was sixty-two to the minute, but after cooked food was seventy-two to the minute. Another speaker attributed many of our maladies to our pride in walking upright on our hind-legs. As a result, the muscles, especially of the abdomen, lose tone and allow the stomach, the intestines, and other organs to sag. To obviate all this the patient should live in the open, do upside-down exercises, and walk on all-fours. This is very grave and welcome advice. We think that people who attend scientific conferences, or religious services, or even those select individuals who are called upon to enter the Houses of Legislature at Westminster, might set the example of doing so on all-fours. Large crowds might possibly assemble to witness such a singular spectacle, and this would serve as an advertisement of the benefits which osteopathic science is likely to confer upon humanity. We might even set ourselves to invent dances on all-fours, not to mention new kinds of military exercises. A Commander-in-Chief would be well advised to order an all-fours march-past of his troops in full uniform, and even levées might be lightened by the same procedure. We hope, at least, that our learned societies will soon set the example.

The Industrial Institute

In our last issue we gave a short account of this new body which is now in course of formation. Its address is 102 Belgrave Road, S.W.1, and there is a long list of Vice-Presidents and Council, which include many men of distinction in various lines. The Director is Mr. Norman Wyld.

Notes and News

The King's Birthday Honours List did not contain the names of many men of science, and those few who obtained recognition in the list held official positions. In the Order of the British Empire Sir Frederic Kenyon, Director of the British Museum, received the G.B.E., Dr. J. S. Flett, Director of the Geological Survey of Great Britain, the K.B.E., and Dr. G. Rotter, Director of Explosives Research, War Office, a C.B.E. In addition a knighthood was conferred on Prof. J. Robertson, Medical Officer of Health, Birmingham, and Professor of Public Health in the University of Birmingham.

The gold medal of the Linnean Society has been awarded to Prof. F. W. Oliver, of University College, London, for his work in botany. Dr. A. B. Rendle has been elected President of the Society for the year 1925–6.

The Albert Medal of the Royal Society of Arts has been awarded to Sir David Prain for his application of botany to the development of the raw materials of the Empire.

On the occasion of the celebration of the centenary of Faraday's discovery of benzene the following were appointed Honorary Members of the Royal Institution: G. E. Bertrand, Professor of Biological Chemistry at the Sorbonne; E. J. Cohen, Professor of Chemistry at Utrecht; Prince Ginori-Conti, president of the Italian Association of General and Applied Chemistry; J. F. Norris, Professor of Organic Chemistry at the Massachusetts Institute of Technology; J. Sakurai, President of the Japanese National Research Council; F. Swarts, Professor of Chemistry at Ghent.

In connection with the Centenary it was decided to award, at distant intervals, possibly six years, a medal for distinguished work having some relation to Faraday's discovery, and it was further decided to give the first of these medals to Mr. J. Morton for his work on anthracene dye-stuffs.

Prof. A. S. Eddington, the Hon. Sir Charles Parsons, and Dr. N. Bohr have been elected foreign members of the National Academy of Sciences, Washington. Prof. Bohr has also been awarded the Barnard Medal of the University of Columbia, which is awarded every five years for meritorious service to science.

Among those whose death was announced during the last quarter were the following: Sir Wm. Fletcher Barrett; Dr. F. E. Beddard, zoologist; Dr. A. G. Butler, entomologist of the Natural History Museum; Dr. J. H. Clarke, State Geologist, N.Y.; Mr. D. B. Dowling of the Canadian Geological Survey; M. Camille Flammarion, astronomer; Dr. A. Haller, For. Mem. R.S., Professor of Organic Chemistry at the Sorbonne; Prof. J. F. Hayford, civil engineer and geophysicist; Prof. G. Körner of Milan, organic chemist; Mr. N. L. Roth, anthropologist; Mr. R. B. Seager, American archæologist.

The Royal Observatory, Greenwich, celebrated the 250th anniversary of its foundation in July last. The actual date was somewhat advanced in order that the astronomers visiting this country for the meeting of the Astronomical Union might share in the proceedings. The most noteworthy feature of the celebrations was the visit of the King and Queen to the Observatory—noteworthy because this was only the second royal visit in its history. There is no record that Charles II, who took so much interest in the foundation, ever visited the institution, and the only other royal visitor was George III.

The Commissioners for the Exhibition of 1851 have made the following appointments to Senior Studentships: Mr. O. M. B. Bulman, Imperial College of Science (Geology); Mr. P. A. M. Dirac, Cambridge (Mathematical Physics); Mr. I. R. McHaffie, University College, London (Physical Chemistry); Mr. H. W. B. Skinner, Cambridge (Physics); and Mr. D. L. Thomson, Aberdeen (Bio-chemistry).

The Ramsay Memorial Fellowship Trustees have made the following awards of new Fellowships for the session 1925–6. A British Fellowship of £300 tenable for two years, to Mr. G. A. Elliott, B.Sc., for work at University College, London. A British Fellowship of £300, tenable for one year, to Mr. H. R. Ing, M.A., D.Phil., for work in the University of Manchester. A Glasgow Fellowship of £300, tenable for two years, to Mr. T. C. Mitchell, B.Sc., for work in the University of Cambridge. A Glasgow Fellowship, of £300, tenable for one year, to Mr. J. D. Fulton, M.A., B.Sc., for work in the University of Manchester. A Canadian Fellowship to Mr. D. McKay Morrison, M.Sc., Ph.D., for work in the University of Cambridge. A Japanese Fellowship of the value of £370, to Dr. Seisi Takagi, for work at University College, London. Sir Robert Waley-Cohen, K.B.E., has been appointed a Trustee of the Ramsay Memorial Fellowship Trust, in place of the late Sir George Beilby.

The University College of South Wales and Monmouthshire has issued a pamphlet containing particulars of courses *and careers* open to students in the Faculty of Science. It is not a prospectus of the usual type, and gives no details as to fees, staff, or time-tables, but it does contain much admirable advice to the student who looks to his college career as a means to an end—the earning of an honourable and intelligent livelihood. In these days, when it is fashionable to deprecate this aspect of a university career, it is refreshing to find it not merely recognised but assisted in so altogether an admirable a fashion.

It has been decided to hold a British Optical Convention at the Imperial College of Science, South Kensington, in July 1926, in order to advertise the important developments in British optical apparatus and instruments which have taken place in recent years. A guarantee fund of £2,000 is required, and the Council of the Optical Society has agreed to contribute £200 towards that total.

The value of research in pure science, *i.e.* that aiming at the acquisition of knowledge without immediate utilitarian objectives, was emphasised in the Report of the Visiting Committee of the Bureau of Standards, Washington, U.S.A., and the Committee expressed the belief that such work should be undertaken by the Bureau to a greater extent than has been done in recent years. It points out that the history of civilisation is filled with illustrations of the utilisation for the good of humanity of the results of scientific work, undertaken without reference to its direct value, and often remaining unused long after its first announcement. Illustrations given are the electrical industry, radio, the vacuum-tube, X-rays, and radium. In each case the fundamental discoveries that made invention possible were made without thought of possible utility. Similarly, the present-day study of atomic physics is cited as a line of research that is likely in the future to yield results of vast proportions, and as yet undreamed of. The report also calls attention to the value of industrial research—a value more generally realised. Numerous examples of savings effected by such research at the Bureau of Standards are given. Studies of certain problems pertaining to the automobile industry are cited, whose combined result is a saving of $155,000,000 per year to the American public. Both types of research, the Committee believes, are essential to the welfare and industrial prosperity of the nation. The economies resulting from them are often very considerable, and are necessary if America is to maintain its present high wage rates and high standards of living in the era of intense industrial competition upon which the world now appears to be entering. The desirability of having research conducted by a national institution is emphasised. Its value depends on the extent to which the results are utilised rather than upon the cost of the work, and a national laboratory such as the Bureau of Standards can afford to give its results freely to all who can profit by them, whereas a private laboratory cannot always be expected to do so.

The desire of several countries that the Central European (enemy) Powers should be admitted to the various scientific unions formed during or since the war with statutes expressly forbidding their admission, has caused some trouble at meetings held during the past quarter. The ruling body in such matters is really the International Research Council. In order that this Council may alter any of its statutes the alteration must obtain the support of two-thirds of the countries adhering to it, and apparently this support must be given by the delegates at one of its meetings. Delegates have votes proportional in number to the population of the countries they represent, and two-thirds of the total implies fifty-three votes. At a meeting held at Brussels (July 7–9) seventeen delegates, representing fifty-two votes, were present, so that even if they had been unanimous no statutory changes could be made! The admission of Germany and Austria to the Convention was pressed strongly by certain of the members; but nothing could be done, and it does not seem likely that any changes will be possible until the present arrangement comes automatically to an end in 1931. The same question was discussed at the meeting of the International Astronomical Union, which took place at Cambridge during the period July 14–22, under presidency of Prof. W. W. Campbell, of the University of California, and with much the same result. The next meeting of this Union has been arranged to take place in Holland in 1928; Prof. Sitter has been elected president for that meeting.

In a letter to *Nature* (July 18) Prof. Nagaoka gives a preliminary account of his successful attempt to effect the transmutation of mercury into gold by passing a high voltage discharge between iron and mercury electrodes in paraffin oil. The first experiment was made on September 15, 1924, and after four hours' discharge gold was detected in the mercury oil-sludge by the Cassius' purple test. Later specks of gold were extracted from this sludge. In subsequent experiments the iron electrode has been replaced by tungsten, and the presence of gold is shown by the formation of patches of ruby glass on the sides of a flask used to contain the residue during its purification. It is hardly mecessary to state that the results have been checked by blank experiments designed to determine whether traces of gold were present in any of the apparatus used. The mercury, after treatment, also yields a white metal, which has not yet been obtained in sufficient quantities to permit of chemical tests.

An account by Prof. Dayton C. Miller of his experiments on æther drift is given in *Nature*, July 11, 1925. The experiments were carried out at Mount Wilson at different periods of the year in 1921 and in 1924–5 under all kinds of conditions, the apparatus being reconstructed during the interval between the two sets of experiments. The observations have always given the same result and indicate that, at Mount Wilson, the motion of the æther relative to the earth is about 10 ± ·5 kilometres per second, *i.e.* approximately one-third of the earth's orbital velocity. Further experiments are in progress, and it is hoped that by the end of the year definite indications regarding the motion of the solar system in space may be obtained. The results are entirely opposed to the Relativity Theory as it now stands, and are moreover difficult to reconcile with ordinary astronomical observations. Hence very definite confirmation will be required before they are generally accepted. It may be noted that experiments with the same apparatus in a cellar at Cleveland in 1905 gave a relative velocity of 3·5 kilometres per second.

The Royal Society has issued another book containing accounts of certain aspects of modern science in connection with the science exhibit at Wembley Exhibition. It is entitled *Phases of Modern Science*, and may be obtained from Messrs. A. and F. Denny, Ltd., 163A Strand (price 3*s*. 6*d*. net). Provided with an interesting frontispiece illustrating the range and character of electromagnetic waves, it contains twenty-three articles dealing with subjects of present-day interest in science, *e.g.* " Radiation " (Sir Oliver Lodge); " Electricity and Matter " (Sir Ernest Rutherford); " The Origin of Spectra " (Prof. Fowler); " The Water in the Atmosphere " (Dr. G. C. Simpson); " The Origin of Man " (Sir Arthur Woodward). Many of these articles are abstracted from lectures of a popular or semi-popular type, and they present in simple language the latest results and theories in their respective subjects.

One of the most pleasant ways of keeping in touch with the advance of scientific thought is provided by the special lectures (*e.g.* of the memorial type) which are delivered from time to time by leaders of science and then printed for the benefit of a larger audience. Such lectures are generally delivered before an audience not specially versed in the subject chosen by the lecturer, and are therefore couched in language which can be understood without difficulty by those who possess very little preliminary knowledge of the subject. Unfortunately, the publication of these lectures is not widely advertised, the sale is small, and the cost relatively large. Four such lectures have reached us this quarter: *The Crystalline State*, by Sir William Bragg (Romanes Lecture, Oxford, Clarendon Press, price 2*s.*); *The Structural Units of the Material Universe*, by Dr. F. W. Aston (Seventh Earl Grey Memorial Lecture, Humphrey Milford, Oxford University Press, price 1*s.*); *The Structure of Light*, by Sir J. J. Thomson (Fison Memorial Lecture, Cambridge University Press, price 2*s.* 6*d.*); and *The Carbon Atom in Crystalline Structure*, an Address delivered by Sir William Bragg at the Centenary Celebration of the Franklin Institute. None of these contains anything very novel from the point of view of the physicist, the latest facts being some months old, but they do summarise in a clear and simple fashion the recent advances in the several subjects, and, what is of no less interest, they contain the thoughts of the men who are leading the advance and indicate the line of future attack. The first and second of these pamphlets can be recommended to the notice of those who are interested in the problems of atomic and crystalline structure; Dr. Aston's analogies should be particularly interesting to teachers. Sir J. J. Thomson's address contains a simple account of an attempt to reconcile the conflict between the undulatory and the quantum theories of light. The fourth lecture is apparently not on sale, and is therefore not readily accessible in this country.

The *Report of an Enquiry into the Conditions affecting the Teaching of Science in Secondary Schools* (H.M. Stationery Office, Adastral House, Kingsway, W.C.2, price (by post) 3½*d.*), which has been prepared for the information of the Board of Education by five of its inspectors, is a document worthy of the most careful consideration by both teachers and school managers. It is based on an investigation of thirty-nine large secondary schools for boys, and indicates a very great diversity in the conditions under which science is taught. Thus the annual cost per head, counting only boys receiving instruction in science other than nature study, varies fron 2*s.* 2*d.* to 33*s.*, figures which include the cost of both apparatus and laboratory attendants. For apparatus and materials alone the cost ranges from 1*s.* 8*d.* to 20*s.* 3*d.*

This statement of cost includes all branches of science; it is unfortunate that it has not been dissected so as to show, for example, the relative expenditure on physics and chemistry. Apparatus was found to be satisfactory save in mechanics, where there is a tendency to use expensive toys instead of real machines. Accommodation, on the whole, was poor, due to lack of building in recent years, to the large increase in the number of boys taking science, and to the institution of advanced courses. There is a marked deficiency in laboratory attendants, one of the worst and most expensive forms of "economy." The comments on the teachers are curious. Many laboratories, it is stated, are run badly, the teachers lacking the necessary experience to make the best of the means at their disposal, and, when new apparatus is to be bought, not knowing what to buy or where to buy it. Further, the Report *seems* to deplore excessive specialisation, and to regret that, as a rule, a science master sticks to his job, not teaching history, a language, or even two branches of science. This is delicate ground—for inspectors! It is quite certain that a teacher who really gives his mind to the teaching of chemistry, or physics, or biology, trying always to improve his teaching, to inspire his pupils, and to know something about the advances in his subject, has really a full-time occupation. A man who attempts more than one subject must be an object of suspicion until his competence is proved. The really important question is, whether it is possible *to inspect in more than one subject.* An inspector should be an expert, not merely in inspection, but in the subject in which he inspects, if his criticisms are to have any constructive value.

One point in the report deserves special consideration. In the section on Curricula the inspectors criticise the syllabus in Physics at the General School Examination of the University of London on the ground that Mechanics, Heat Light and Sound, and Electricity and Magnetism form three separate subjects, so that a candidate may take one and be quite ignorant of both the others. This is sound criticism; but the position would not be improved in the least by adopting the procedure at the corresponding examination held by the combined Northern Universities. This year, for example, at that examination, the Physics paper was a six-paged pamphlet of twenty-six questions, from which (with certain small restrictions which do not affect the present argument) the candidates had to choose nine. This does not ensure that the teaching covers the whole of the Physics syllabus; it puts a premium on scrappiness, and is entirely ridiculous. If it is the opinion of the Board of Education that Physics should be treated as one subject the papers should be so arranged as to ensure that an appropriate syllabus, including all its branches, is properly covered.

Technical Paper No. 11 of the Fuel Research Board (H.M. Stationery Office, Adastral House, Kingsway, W.C.2., price 4*s*. 6*d*.) contains a most interesting series of microphotographs of the structure of a coal-seam. Horizontal and vertical sections of the seam are taken at intervals of 1 inch from the seat earth to the roof of the seam, and then photographed with a magnification of 20 diameters. The paper contains reproductions of one hundred of these sections taken from the Lanterne Seam of the South Wales Coal-field in the Lomax Palæo-botanical Laboratory by Mr. J. Lomax, who has prepared a series of such microphotographs from many of the more important seams in the country. The reproductions show many beautiful examples of well-preserved plant structures; suitable notes on each being given in the letterpress. The Introduction, by Mr. R. V. Wheeler, contains one curious sentence. He says that " This report . . . should have a high educative value." Presumably there is really none of the doubt implied by the " should," for the monograph must have been distinctly expensive to produce, and it should have been possible to determine its value beforehand.

The reclamation of petrol used in dry cleaning is discussed in Technologic Paper No. 280 of the Bureau of Standards, Washington. A number of the processes which have been utilised for this purpose are discussed and criticised, and that which has proved most satisfactory is described in detail, indeed working plans for plants of different sizes are provided. The process recommended consists in mixing " activated " carbon (*i.e.* carbon specially treated to increase its decolorising power) with petrol, and then pouring this wetted carbon into the dirty petrol from the storage tank. Finally, the sludge formed is induced to settle quickly by the addition of a water solution of trisodium phosphate. In the course of a short time (*e.g.* an hour) the petrol is cleared and can be syphoned off as a water-white product. It is stated that 2,200 gallons of dirty petrol may be purified with 15 lb. of trisodium phosphate, and 13 lb. of activated carbon. The quantity, of course, depends on the extent of the dirtiness, but the cleaning agents can be used several times—until the syphoned liquid ceases to be white.

An interesting account of the Finno-Ugrian peoples is given in a monograph (in English) entitled, *The Genealogy of the Finns,* by U. T. Sirelius (Government Printing House, Helsinki, 1925). This race includes the Finns, Esthonians, and Magyars, who form independent civilised States, and, in addition, the Carelians, distributed in various parts of Russia;

the Lapps, estimated to number only 30,000 persons, of whom 20,000 live in Norway; the Mordvinians, and Cheremisses who, to the number of about 2,000,000, inhabit the Volga region; the Votyaks and Siryenians, mostly living in the Permian region of Russia, and the Voguls and Ostyaks in Siberia. No systematic anthropological research covering all these peoples has yet been carried out, but it is clear that they no longer form a stock which is even approximately homogeneous. Their origin is uncertain; there is no conclusive proof that they are related to the Mongolians, and, having regard to certain ancient common roots, it seems more probable that they belong to the Indo-Germanic group. The monograph is illustrated by many photographs, and contains an account of a number of curious customs, from among which the following may be quoted. It refers to a modification of marriage by capture which used to be practised by the Mordvinians. "At midnight the bridegroom's father put a crust of bread with honey on the gate-post of the house from which the girl was desired, and then approached a window and courted her on his son's behalf. If he afterwards escaped without being caught by the girl's father and his friends, the courtship was regarded as binding."

Volume iv of the *Chapters in the History of Science*, edited by Dr. Charles Singer, is entitled, *The History of Mathematics in Europe*, and is written by J. W. N. Sullivan (London, Oxford University Press, 1925, price 2*s.* 6*d.* net). The period treated extends from A.D. 600 to the work of Laplace, and, although the book contains only 110 pages and is plentifully illustrated with diagrams and portraits, the author has succeeded in making the story an extraordinarily interesting one. With so small a space it necessarily follows that only the most important steps in the history of the subject could be touched upon, and this is really an advantage from the view-point of those unacquainted with the history. Reproductions of original MSS. and examples of the notation employed in the pre-Newtonian period help to make clear the difficulty which mathematics, even of the simplest kind, must have presented in those days.

Students of chemistry will feel grateful to Mr. W. H. Patterson, of East London College, and to Messrs. Methuen for the translation and publication of Arndt's *Summary of Physical Chemistry* (pp. 92, price 3*s.* 6*d.* net). It contains a brief account of all the fundamental facts and theorems required by a student preparing for an Honours examination expounded briefly but in a connected and reasoned manner. The book will also be found useful to the physicist for reference purposes.

Messrs. Williams and Wilkins & Co. of Baltimore, U.S.A.

(London Agents: Baillière, Tindall and Cox, 8 Henrietta Street, Covent Garden) have published a book entitled, *Preparation of Scientific and Technical Papers*, by S. F. Trelease and E. S. Yule (price 7*s*. 6*d*.), which should be read by every postgraduate student. It forms a complete guide to the preparation of a paper and to the correction of its proofs. Such a work is badly needed, and the book should find a place in every college library.

Early this year Sir Arthur Schuster, F.R.S., contributed a short but interesting paper to the Royal Society on the "Life Statistics of its Fellows" (*Proceedings A*, vol. cvii, 1925). He concludes that the average "life of Fellows of the Royal Society is, on the average, nearly six years longer than that given in the tables which have been used"—he means the Table of Life Statistics published in *Whitaker's Almanack*. This will be encouraging news for surviving Fellows who are advancing in age.

Messrs. Blackie & Son have recently issued an admirable book called *Evolution in the Light of Modern Knowledge*, consisting of essays on the subject written by thirteen contributors, all distinguished for their work in this line. The book has reached us too late for a review in this number, but the excellence of the essays deserves wide attention, and the book promises to become a scientific classic (see Books Received).

We have received some more literature on the subject of Rabbit and Rat Extermination from the originator of the method advocated, namely, Mr. W. Rodier of 327 Collins Street, Melbourne, Australia. His polemics on the matter are always extremely amusing, and are illustrated with amusing drawings, especially that of the Sceptic scratching his long and hairy ear. From what the author tells us his method is gradually beginning to gain favour in Australia. Those who have themselves tried to induce men to save their own lives on the large scale, with but slight success, will know how difficult it is to persuade the hairy-eared gentlemen who compose the mass of the public to try anything new, even in the interests of their own health, much less in those of their possessions.

ESSAYS

THE ANIMATE MODEL OF PHYSICAL PROCESS (Joshua C. Gregory, B.Sc.).

THE startling burst of heat from watered lime excited speculation in seventeenth-century chemists and their predecessors. In one tradition it was a response to a threat. The internal heat of the lime was menaced with quenching by the cold of the water, and invigorated by the menace. This increase of a " besieged quality " to resist attack from another was not confined to the internal heat of lime. Authority, reason, and experience were presumed to confirm *antiperistasis*. Boyle (1627–91), noted the vogue of this doctrine, and a general belief in its application to the heating of slaked lime.[1] Principles often acted, according to Sir Francis Bacon (1561–1626), with increased energy through the antiperistasis of their opposites. Such antiperistasis, resistance roused by a threat from an opposite, was one alternative explanation, Bacon also suggested, of the heat emitted by watered lime.[2] This principle was familiar enough to be applied, during the seventeenth century, to the doubling of penury by the antiperistasis of plenty in others, and, in 1703, to the spiritual antiperistasis that increased the heat of grace against the cold blasts of persecution.[3] Antiperistasis in physical science, as in other spheres, was the reaction roused in a quality, or some principle, by a threat from its opposite.

A squeezed gas resists more violently as it is more compressed, but neither this nor other purely physical occurrences were responsible for antiperistasis in physical phenomena. Menace obtrusively quickens animals or men into vigour. The desperate turn of a cornered animal upon its assailant, the fierceness stirred by anger, and men braced by emergencies, are more likely sources for the doctrine. Bacon, perhaps unwittingly, when he recognised the same antiperistasis in both physics and the contests of factions,[4] hinted at an animate model of physical theory. Boyle deprecated the comparison of inanimate cold and heat to self-invigorating living creatures. Inanimate agents acted by necessary impulse that permitted no resilient collection of power against opposites.[1] This implication of an animate model applied to physical process in antiperistasis is confirmed by the nature of the general mental milieu. One key to the course of physical science is the primacy of the animate, or psychical, model in interpretations of nature. The doctrine of antiperistasis was a consequence of an inveterate preconception, and remains an historical index of it. Chemistry did not break decidedly with an old predilection for attributing animate habits to inanimate substances until the end of the seventeenth century. No single date is an absolute dividing line between animistic chemistry, with its hankering after the animate model, and mechanised chemistry, with its preference for the mechanical situation. Chemists like Boyle had substantially forsaken the animate model of physical process before the seventeenth century closed. There were survivals of the old mental habit well after the eighteenth century began. A.D. 1700, however, is a convenient, significant single year to date a virtual exclusion of an inveterate preconception from physical science. Rational science was domiciled in Europe, according to Berthelot, in the eighteenth century.[2]

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[1] Birch, *The Works of the Hon. Robert Boyle*, 1772, ii, p. 660 ; iii, p. 479 ; iv, pp. 60, 246.

[2] Bacon, *Novum Organum*, ii, 12, 13; *Historia Ventorum ; Historia Densi et Rari.*

[3] Murray, *New Eng. Dict.*, 1888.

[4] Macaulay, *Essay on Lord Bacon.*

If the parallel between the *microcosm* and the *macrocosm* was explicitly drawn in Babylonia, long before the Christian era, as Berthelot averred,[3] thought openly announced, at an early date, its propensity to think of things as if they were alive. Man, the microcosm, reduplicated the universe in which he lived, the macrocosm. Man was a miniature universe ; the universe a magnified man. Inference could proceed from the macrocosm to man ; deduction, relevantly to the present theme, could inversely extend from the microcosm to the universe without. When Albertus Magnus (1193–1280) affirmed that man is, in a sense, the microcosm or image of the universe,[4] he repeated a constant mediæval tradition. Correspondence between microcosm and macrocosm has been called the central dogma of mediæval science between 400 and 1543. The speculations of the *Timæus* were grateful to this indurated mediæval doctrine.[5] When Plato wrote the *Timæus* in the fourth century B.C., he prepared a constant source of cosmological and physical concepts for his successors

[1] Boyle, *loc. cit.*, ii, pp. 662–3.

[2] Berthelot, *Les Origines De L'Alchimie*, 1885, Pref.

[3] Berthelot, *loc. cit.*, p. 51.

[4] Thorndike, *A History of Magic and Experimental Science, etc.*, 1923, ii, p. 577.

[5] Singer, *Mediæval Contributions to Modern Civilisation*, ed. Hearnshaw, 1921, pp. 114 ff.

and the Middle Ages. Jowett, in his introduction to the *Timæus*, commented on its obscurity and repulsiveness to a modern reader. Its confusions, however, because they were natural to the infancy of physical science, were congenial to early and mediæval minds, and no other writing of Plato's equalled it in influence over the pre-modern world. Curious as Haskins considers the fact, the influence of Plato persistently pervaded the Middle Ages.[1] The comparison of the world, or universe, to an animal, that is the backbone of the argument in the *Timæus*, has an obvious affinity with the microcosm and macrocosm parallel. Bacon charged the philosophy of Pythagoras with planting the " monstrous imagination " of a world which was " one entire perfect living creature," and accused Plato and others of watering and nourishing it.[2] The attempt to unite contrary excellences in a single figure was connected by Sir Joshua Reynolds with degeneracy into the monstrous ; the philosophical attempt to compress the universe into one single creature had inevitably extravagant results. The belief flourished and prospered : a Stoic tenet identified the world with an animal.[3] Donne, preaching in the seventeenth century, spoke of man's body as God's recapitulation of nature.[4] From the sixth century before Christ Greek medicine treated man as a miniature universe.[5] The deliberate parallel between the microcosmus in man and the macrocosmus in the world was drawn in Babylonia and in Greece. It was fostered by Plato and the Platonic tradition. It dominated the mediæval world. That whirlwind of the Renaissance, Paracelsus (1493–1541), who swept like a storm through the first half of the sixteenth century, preserved the ancient opinion that man was an abstract or model of the world. He and the alchemists, Bacon noted, strained the parts of the human body into fantastic correspondences with stars, plants, minerals, and all the furniture of heaven and earth.[6]

The modern *microcosmic salt*, which occurs in the secretions of microcosmic man, is a relic of an old, dominant doctrine. Boyle recorded the just complaint of Heraclitus, some five hundred years before Christ, that men searched the microcosm for knowledge of macrocosmic things.[7] In 1543 Paracelsus still tempted thought into interpreting the physical world as if it resembled an animal or a man. The microcosmus-macro-

[1] Haskins, *Studies in the History of Mediæval Science*, 1924, p. 88.

[2] Bacon, *Nat. Hist.*, x, 900.

[3] Berkeley, *Siris*, 1744, Par. 194.

[4] *Donne's Sermons*, selected by Keynes, 1923, p. 124.

[5] Brett, *A History of Psychology, Ancient and Patristic*, 1912, p. 18.

[6] Bacon, *Adv. Learn.*, ii.

[7] Boyle, *loc. cit.*, iv, p. 165.

cosmus parallel, though many concepts conspired to make it, was, in one aspect, an explicit expression of an inveterate predisposition. Primitive animism clearly reveals an inclination implanted in the human mind to model physical things on conscious, or animate, beings. Elliot Smith and Perry regard primitive personification as more an occasional than a prevalent habit. Primitive personifications are specifically prompted confusions of objects with human beings.[1] Absolutely indiscriminate animism need not be charged against the primitive who clearly reveals a pervading predisposition to think of physical things as if they were conscious, or animate. Nor was the animate model indiscriminately applied, without qualification or remission, to the study of physical things from Plato and Aristotle to the end of the seventeenth century. The human body is the typical physical object,[2] and was the primary model of physical things. Animism frankly extended its animation and consciousness into inanimate nature. The doctrine of the microcosm and the macrocosm expressed a persistent comparison of the inorganic world to living beings. The doctrine of antiperistasis disclosed the haunting of inanimate things by concepts derived from animate existence. The mechanism of the physical world, the qualities of non-living things, and physical processes were primarily modelled on the natures, qualities, and methods of performance discovered in the animate world. Primitive animism proceeded from this fundamental predisposition; the microcosmus of mediæval theory explicitly confirmed it; till the seventeenth century closed it constantly pervaded chemistry. Deductions from human beings, animals, and plants constantly invaded interpretation of the physical world. The vogue of the animate model of physical process is constantly discernible in speculative science till Descartes prompted its expulsion during the seventeenth century.

Jean Rey did not argue superfluously in 1630 that lead was not alive.[3] From about 800 to 1400 the Arabian alchemists often compared the conversion of "imperfect" metals into "perfect" gold to the treatment of sick men with drugs.[4] The totemistic Australian who regards the kangaroo as his clansman presumably realises that men and kangaroos are not identical. The Arabian alchemist could distinguish metals from men without prejudicing the fundamental analogy between the furnace for imperfect metals, or the elixir for their perfecting, and the hospital for the sick. The comparison between metals and sick men was literal, but not absolute.

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[1] Appendix by Elliot Smith to Rivers, *Conflict and Dream*, 1923, pp. 189 f.

[2] Broad, *Scientific Thought*, 1923, p. 444.

[3] *Essays of Jean Rey*, 1630, Alembic Club Reprint, No. 11, 1895, p. 38.

[4] Kopp, *Geschichte der Chemie*, i, 1843, p. 47; Holmyard in SCIENCE PROGRESS, 1922, **17**, Arabic Chemistry, p. 257.

Many alchemists, Nicolas Lemery noted in the later seventeenth century, sought the "seed" of gold in gold itself, as they might search a plant for the seeds that propagated it. They also searched in other metals, and even in vegetables.[1] Seminal and plastic powers, suggested by growth from seeds or other vital phenomena, were still invoked for physical things in the seventeenth century. Some chemists still applied seminal principles to metals, and extended to the inorganic world the fermentative action of dough or maturative powers. Even Boyle, who insisted on the mechanical model for physical process, occasionally hinted at animate habits in physical things. He implied recourse to the animate model in others, and affirmed his own ordinary mechanical methods of interpretation, when he protested against seminal principles in inanimate things. He deprecated the comparison of purely chemical processes to transformations in animals or plants under the plastic power of the seed, or something analogous. He questioned the operation of an "architectonick principle" in the regularity of alum crystals: disposing powers were presumed to direct the geometric regularity of crystallisation as well as the freer growth of plants. "Divers subterraneal bodies," however, seduced him into a speculative return to the animate model. He suspected them of constantly emitting effluvia, and, since they were incessantly active, of possessing a "propagative, or self-multiplying power."[2]

It was known in the sixteenth century that the red product of calcined lead was heavier than the original metal. It was also a received tradition that a dead body weighed more than when it was alive. The contrast between the dead weight of a corpse and the pliancy of a living burden probably originated the belief: some apparently thought that the dead body did weigh more because it could not assist in its own removal. The recess of animal and vital spirits was noted by Boyle as the usual explanation. The light, agile spirits enlivened the living body, diminished its weight, and left it heavier when they withdrew in death.[3] Cardan compared the red calx of lead to the dead body of the living metal. The lead lost its soul in the furnace, and the dismembered metal, deprived of its enlivening principle, left a corpse heavier than itself.[4] Rey's argument was directed specifically against Cardan. Plants and animals had grouped, or co-ordinated, organs, he urged, but lead had none. The calx of lead, because it could be restored to metal by heating with charcoal, was unlike the corpse that could not return to life. Rey protested against an inveterate preconception, for metals suffering from sickness, ripening from seeds, and provided with souls, were subject to the vogue of the animate model of physical process.

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[1] Lemery, *A Course of Chymistry*, transl. Harris, 1686, pp. 49–50.

[2] Boyle, *loc. cit.*, i, p. 509; iii, pp. 522–9; v, pp. 46, 410.

[3] Boyle, *loc. cit.*, iii, p. 589.

[4] Cardan, *de Subtilitate*, 1550, Bk. 5.

The obtrusiveness of this vogue in metals, antiperistasis, and in the microcosmic parallel with the macrocosm, suggests the surmise that the traditional preference of like for like presupposed, though it might often be unwittingly, animate habits in inanimate things. Hippocrates, about the fifth century before Christ, whether he were a single man or a syndicate of physicians, thought that like unites with like,[1] and, though Aristotle admitted the indiscriminate collection of homogeneous and heterogeneous things together by cold as well as the segregation of kinds by fire,[2] Stahl, as the eighteenth century opened, tried to prove that only resemblants combined,[3] and Beccher, just before him, that uniting substances had a common principle.[4] The mediæval readers of the *Timæus* would be familiar with a cosmic scatter of unlike elements, and a close contact between those that were most similar. They would be familiar with battles between elements in which, if substances did not escape to their own kin, they were assimilated to their victors that they might dwell with them. They would be familiar with weight as a tendency towards kindred elements. They would be inveterately predisposed towards approaches between likes and repugnances between unlikes. Attraction, or attractive forces, did not become an effective chemical, or physical, concept till Newton impressed it upon eighteenth-century science. So long as the notion of attraction lurked subordinatively, or received casual attention, so long as it waited in the queue of concepts that waited for recognition, it was dominated by the preference of like for like. When Bacon suggested attractive forces he conformed them to this preference. He thought that the "very forcible shoot" of the "Turkish Bow" could drive a wooden-headed arrow through eight inches of beam because wood attracted wood. The attraction of the target for its kindred wood augmented the pierce of the springing bow. The "motion of attraction," he added in the spirit of the traditional preconception, was by "similitude of substance." Indiscriminately acting gravity killed the draw of lead upon lead, or of gold by gold, unless violent motion, like the rush of a sped arrow, killed gravity itself and allowed similar substances to indulge their natural attractions.[1] The preconceptive influence of presumed approaches between likes is evident in Bacon's speculations. In the constant tradition from Hippocrates to Stahl that unions occur between likes the animate model may be surmised in versions of physical process. An ass to an ass seems beautiful; a pig to a pig, so ran the old saw. Perhaps deliberately by some and unwittingly by others, the clannishness of life may have been imported into physical combinations.

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[1] Kopp, *loc. cit.*, iii, 1845, p. 55.

[2] Aristotle, *De Generat. et Corrupt.*, ii, 2.

[3] Fourcroy, *Elementary Lectures on Chemistry and Natural History*, transl. Elliot, 1785, i, p. 36.

[4] Kopp, *ibid.*

The animate model is more surely discernible in seventeenth-century doctrines of strife between opposites. Though hostility between acids and alkalies was a metaphorical phrase for a mechanical process from some pens, distinct animistic implications lingered in descriptions of effervescent encounters. Boyle's criticisms implied attribution of literal duels to alkalies and acids. He was dissatisfied with the fundamental notions of hostility between acids and alkalies, and of friendship within their tribes. Morals and politics were inappropriately introduced into purely mechanical transactions.[2] The haunting of the acid-alkali relation by animism lingered curiously in Hermann Boerhaave. A female alkali impregnated by a male acid suggests an animistic relic. When Boerhaave wrote his systematic treatise in 1732 he insisted that chemistry changes by motion alone, and constantly propounded mechanical explanations, even of effervescence between alkalies and acids. Yet a male spirit of nitre (nitric acid) generating its own kind by producing nitre from many fixed alkalies, whether they were obtained by deflagrating nitre, or from tartar or potash, suggests a lingering vogue for the animate model. Boerhaave may have metaphorically introduced sex without animism into the acid-alkali relation, and trusted his contemporaries to avoid misconception. If his female alkalies and male acids were only metaphorical survivals, they were nevertheless survivals of an attribution to inanimate bodies of animate habits.[3]

The *spiritus rector* of eighteenth-century tradition was the ruling spirit of vegetables, resident in their oils, very volatile, unproducible by art, imparting taste, and lending odour to individual plants.[4] Isaac Hollandus in the fifteenth century, and Paracelsus in the sixteenth, had endeavoured to extract

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[1] Bacon, *Nat. Hist.*, viii, 704.

[2] Boyle, *loc. cit.*, iv, pp. 284 ff.

[3] Boerhaave, *Elementa Chemiæ*, transl. Shaw, 1741, i, p. 135; ii, pp. 249–50.

[4] James, *A Medicinal Dictionary*, 1743, Spiritus Rector.

quintessences from plants by repeated distillations, extractions with alcohol, and other methods. These *quintessent* preparations condensed minute traces of powerful essences, and could animate the " spirits " of other substances. The *spiritus rector* of alchemistic tradition appeared in Boerhaave as the thin, subtle, pure " spirit," that was charged with the plant's fragrance, lodged its taste and colour, and directed its life. Potent in effect and minute in amount, it lay fettered in the oil. As Boerhaave received it from tradition he displayed the influence of the animate model upon its conception. The *spiritus rector* was a chemical soul. The *spiritus rector* of cinnamon, according to Boerhaave, resided as " a very small particle," in a " very small quantity of oil." It had a chemical behaviour, for it could be distilled from a retort or dispersed through water. It also behaved like a purposive, effective mind or soul. It nourished the organism ; it turned many things to the proper nature of the plant by impressing specific characters on the food of the embryo ; it probably breathed a " vital principle." Every animal, as well as every vegetable, had its *aura*, *spirit*, or *spiritus rector*. Each spirit presided over the destiny of a plant or animal. Each had its cycle of residence in the air, an impregnating return to the bosom of earth, a period of directive animation, and a return to air.[1] " Spirits " were traditional combinations of subtlety and power. The term " spirit " was used with apparent inconsistency, now to denote mere volatility and now with a more interior significance,[2] because it was doubly modelled on the physical aspect of the human body and on its informing soul or mind. Sometimes spirits were more physically conceived by an emphasis on the volatile and tenuous nature of their substance. They were often purely material volatiles or fine essences. Sometimes they more emphatically approached the nature of mind or soul. When this emphasis fell most heavily they might be immateriate. Sometimes, like the *spiritus rector* of Boerhaave, they obviously united the physical characters of a tenuous or volatile body with the directive powers of a soul. The vogue of the animate model of physical process is manifest in the eighteenth-century *spiritus rector* and its progenitors.

The eighteenth-century *spiritus rector* throws a retrospective light upon the " ferments " of the sixteenth and seventeenth centuries. Each human being, according to Paracelsus in the sixteenth century, had an alchemist in his stomach : a presiding Archæus sorted out the food into wholesome and poisonous.[3] In the philosophy of Van Helmont (1577–1644) " ferments " were the agents of chemical and physical changes. Boerhaave complained that the alchemists, seduced into wide mental wanderings by casual resemblances, made metals ferment. He restricted the term "ferment" to bodies that excited, increased, and promoted vegetable fermentation.[1] If the action of leaven upon dough, and similar actions, prompted the ferments of seventeenth-century chemistry, the conception spread widely from this original prompting. Boerhaave's *spiritus rector* was confined to animate beings and perhaps restricted to particular operations in them. Van Helmont's ferments were the performers in all changes, and he adopted the Paracelsian Archæi as pontiffs among them. Archæi directed the lives of animals and plants; many minerals and metals, because they grew, had each a presiding Archæus. The animate model had mastered the chemistry of Van Helmont. Each Archæus presided over birth and continued to shape the existence of the being till the end of its life. This spirit had an "idea" of the being it intended to beget, and fashioned it according to that idea. The ferments and pontifical Archæi made little pretence to chemical or physical nature, though they were chemical and physical agents. The *spiritus rector* was material, though exiguously and tenuously; Van Helmont's ferments were spiritual principles, dispersed at the creation throughout the universe.[2] The *spiritus rector* was a chemical soul; his ferments were souls without bodies, or souls incarnate in substances. The notion of a ferment varied with different speculators in its emphases on the material and animate sides, and the *spiritus rector* conveniently typifies the seventeenth-century "ferment." The famous Aristotelian definition, or analysis, of causation was obviously based upon an animate model. It has been succinctly described as "a matter on which an agent impresses a form, in order to express an end or purpose."[3] A potter shaping a jug to hold and pour: that is the obvious model of the influential Aristotelian tradition. The ferments of Van Helmont are irresistible suggestions of efficient Aristotelian causes, corresponding to potters, aiming at ends corresponding to the hold and pour, shaping, corresponding to the formal cause, substances that correspond to the material cause. More concisely, Van Helmont propounded an animistic chemistry: he sprinkled matter with souls.

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[1] Boerhaave, *loc. cit.*, i, pp. 143 f., 168 f., 526 ; ii, pp. 155 f.
[2] Redgrove, *Alchemy : Ancient and Modern*, 1922, p. 15.
[3] Stillman, *The Story of Early Chemistry*, 1924, p. 324.

The animistic chemistry of Van Helmont was dispersed at the end of the seventeenth century. When Boyle compared the material world to an automaton operating mechanically he established a notion in chemistry that was essential for its success. He could mechanise chemistry without the Epicurean affront to Providence by accepting a mechanical world from the hand of God.[1] Chemistry was definitely committed by Boyle, Lemery, and others, to the mechanical model of physical, or chemical, process when the century closed. Van Helmont's animism required a powerful force to disperse it, for his voice did not cry alone in the wilderness. A deferential note runs through the references of subsequent chemists to the famous Belgian mystic. Nor could his philosophy have grown without some consent from the mind of the day. The corpuscular fervour of a group of chemists, that included Boyle, Lemery, and Mayow, provides the cue to the dispersal of Helmontian animism. The invasion of chemistry by the corpuscle in the seventeenth century is one most striking feature of its history. The atom, or corpuscle, had been substantially both barred and banned from the beginning of alchemy, which was the infancy of chemistry, till the seventeenth century. Then it came, conquered, and was domiciled in power. The coming of the corpuscle represents the sweep of a great power into science. Any, or almost any, substantial sample from the profuse writings of Boyle will contain the name of Descartes, and often the name of Gassendi. The clean Cartesian cut between extended matter and thinking non-extended mind offered the material world to the chemist as a mechanical domain. This gave a shrewd blow to animistic chemistry. The corpuscle gave the *coup de grâce*. Descartes, who perpetuated an old prejudice against voids, offered science a crush of corpuscles without interstices. Gassendi offered the old free-moving atom of Greek atomism. The corpuscular mechanism, though it doubtless received its first impetus from the dominating influence of Descartes, leaned on the Gassendi concept. The conviction that mechanical forces operated in the material world was embodied in explanations by corpuscular mechanism. Animism could be accommodated to material machinery, on the analogy of the automatic motor-car controlled by a chauffeur. The corpuscular mechanism substituted an effective agency for ferments and Archæi. During the early years of Descartes after his birth in 1596 Helmontian animism was a power in chemistry. After his death in 1650 Boyle, impressed with the Cartesian mechanical world of matter and equipped with the interpretative corpuscle, steadily, in conjunction with other chemists, committed the science to the dominance of the mechanical model of process. Descartes and the corpuscle, through the great chemists of the later seventeenth century, mechanised the science and disestablished the vogue of the animate model.

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[1] Boerhaave, *loc. cit.*, ii, pp. 106, 119–20.

[2] Metzger, *Les Doctrines Chimiques en France, etc.*, 1923, pp. 165 ff.

[3] Carr, in *Nature*, 1922, 110, p. 471.

[1] Boyle, *The Origine of Formes and Qualities*, 1667, pp. 102–5.

Though Boerhaave freely accepted the mechanical model of physical process, and relied on a corpuscular mechanism for agency, he retained the *spiritus rector* for plants and animals. The Archæus of Van Helmont, Liebig remarked, was transformed into "vital force" during the eighteenth century.[1] Vitalism might be described as a chemistry partially, perhaps very greatly, purged of the animate model of process. Boerhaave surveyed a mechanised chemistry, theoretically based on mechanical models; but he retained the *spiritus rector*, based on the animate model, in the sphere of life. The animate model, now with its animism thickened and now with it thinned, persistently suffused concepts of physical process till the seventeenth century ended. Then the mineral kingdom escaped from its sway. Physical and chemical processes proper were abandoned to the mechanical model. The animate model, however, though expelled from its inappropriate locale, was retained in the more appropriate sphere of animate things. Vitalism, at any rate in one aspect, was this retention. No single phrase or single concept will compass the vitalistic theories of Stahl and his successors; but, in one very real sense, eighteenth century and subsequent vitalism confined to the sphere of life the animate model that once determined the concepts of all chemical and physical processes. The vogue of the animate model is one great feature in the history of human thought. It is one key to the origin, spread, and vicissitudes of many concepts. Its exclusion by the mechanical model of process from all transformations that could be reasonably regarded as physical or chemical was an important moment in the history of science.

SOME CZECH CONTRIBUTIONS TO CHEMICAL SCIENCE

(J. G. F. Druce, M.Sc., F.I.C.).

In May of this year Prof. Bohuslav Brauner, Director of the Chemical Institute of the Charles University of Prague, attained his seventieth anniversary, a fact which has not passed unnoticed in scientific circles in Great Britain and other countries.

The event presents an occasion for a survey of the past and present contributions of the Czechs to our knowledge in the various branches of chemical science.

Prof. Brauner himself is perhaps best known to the English-speaking scientific public on account of his international reputation as an inorganic chemist who has made painstaking investigations in the rare-earth elements, and for his studies in systematic chemistry. These included the early advocacy of Mendeleef's Periodic Classification of the Elements. Indeed, it was largely through Brauner's efforts that the Russian savant's work did not suffer the same fate as Newland's Law of Octaves. Later, Prof. Brauner did much to extend and perfect the system, and many of his discoveries have given support to Mendeleef's scheme.

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[1] Liebig, *Letters on Chemistry*, No. 4.

Prof. Brauner's connection with this country dates from his student days at Manchester (of which University he is Honorary D.Sc.) in the early 'eighties. It was here that he first liberated, in 1881, small amounts of fluorine by decomposition of fluoplumbates. This was prior to Moissan's work—a point which seems to have been overlooked since.

He has made a very careful study of a number of rare-earth elements and their salts. He found that cerium is quadrivalent in many of its compounds, and that the old didymium was complex. From it he succeeded in isolating the elements praseodymium, neodymium, and samarium.

As early as 1877 he had shown that beryllium is bivalent, and therefore has an atomic weight of 9, and takes up the position at the head of the alkaline earth group in Mendeleef's Table. He has published much work on the determinations of atomic weights, making a special study of those of the elements beryllium, thorium, praseodymium, neodymium, lanthanum, and tin. In analytical chemistry he carried out many investigations on the best methods for estimating the elements quantitatively. Many years ago he advocated the oxygen standard as the basis for atomic weight calculations, in preference to taking hydrogen as unity. This suggestion was ultimately adopted by the International Committee. This work, the value of which gradually came to be recognised, gave him some prominence, and he ultimately became a member of the International Committee for Atoms, and is now the president of the Sub-committee for Atomic Weights.

In addition to his original memoirs, he undertook the important task of writing for Abegg's *Handbuch*, the " critical discussions " of the atomic weight determinations of the elements. These have proved of immense value to subsequent workers in this field.

Prof. Brauner's interests are very wide. In addition to being a great traveller and linguist, and possessing a wide knowledge of English fine Art and literature, he is a keen sportsman and mountaineer. He was one of the founders of the Czech Ski-ing Club, and introduced an early type of cycle into Bohemia, participating himself in road races. He is a keen huntsman, and has had many and varied bags. Naturally of late years many honours have been bestowed upon him. These include the Honorary Membership of the Chemical Society (London), and the Croix de Chevalier de la Légion d'Honneur (France). In Bohemia he has done much to foster an interest in science, and through his efforts the new Chemical Institute was erected in 1903.

Since then many important scientific communications have emanated from the Chemical Laboratories of the Charles University. Some of them have appeared in the Transactions of English Societies, including those of the Royal Society, the Faraday Society, and the Chemical Society. But the fruits of his efforts cannot be better exemplified than by reference to the *Jubilee Volume* [1] just issued by Brauner's friends and pupils, in accordance with the continental practice on such occasions. The Czech scientists who constituted the Publication Committee of this volume are to be congratulated upon the high literary and scientific standard of their work. A striking originality and simplicity of method characterises the Czech procedure in attacking chemical problems. Their results are described in a language other than their own. Thus most of the contributions are in English, two are written in German, and a few are in French.

The best-known Czech organic chemist, Prof. E. Votoček, who spent many years in Paris, have contributed, with Dr. Lukeš of the Prague Polytechnic, a paper dealing with the oxidation of the sugar alcohols. This communication is of importance as a contribution to stereochemistry.

Prof. J. Štěrba-Boehm, of the Pharmaceutical Institute of the Charles University, a distinguished chemist who studied under Moissan at Paris, is responsible for two papers (with Mlle Auerspergová and Dr. V. Matula as collaborators), on a study of quadrivalent lead and the volumetric estimation of cerium.

Of three papers from the Brno Technical College two deal with the nitro-compounds of naphthalene derivatives and their reduction products, whilst the third, by Prof. R. Vondraček and Ižák-Križko, describes a very careful investigation on the influence of impurities in zinc on its solubility in acids. There is an unusually interesting article, also from Brno, but from the Masaryk University by Prof. A. Šimek and Mlle Kadlcová, in which a new electro-kinetic phenomenon is recorded. It is found that drops of fused tellurium dioxide on a platinum surface heated by direct current move away from the negative and towards the positive pole. The velocity of movement is found to be proportional to the current strength. Experiments with other substances are also described.

Other interesting topics dealt with in the papers are: *The Exact Potentiometric Titration of Cerium Salts*, by Dr. Tomiček; *Investigations on the Precipitation of Ferric and*

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[1] Numéro jubilaire en l'Honneur du Professeur Bohuslav Brauner publié par ses amis et élèves en Commémoration de son 70e anniversaire.

Ferrous Sulphides, by Drs. Křepelka and Podroušek; *Trivalent Copper*, by Dr. Vrtiš; *Mannitol-Aluminates*, by A. Herasymenko; and *The Action of Vapours of Organic Liquids on the Surface Tension of Water*, by V. Kořan.

The last hundred pages or so are taken up with a description of a series of investigations with the dropping mercury cathode. These researches have been carried out under the direction of Prof. J. Heyrovský, who studied in London under the late Sir William Ramsay and Prof. Donnan at University College. In these there is the first exact determination of the change of over-voltage with the hydrogen ion concentration. A new theory to account for over-potential is given. A feature of the work is the illustration with " polarograms " taken with the aid of Heyrovský and Shikata's " Polarograph."

It is thus evident that Prof. Brauner has laid the foundations of a flourishing centre of research which has quickly attained a high position in science for the free Czechoslovak nation, which has shown so much promise in other intellectual spheres.

THE MOSQUITO-THEORY OF MALARIA AND THE LATE PROF. G. B. GRASSI (Sir R. Ross).

THE death of this well-known zoologist occurred on the 4th or 5th of last May at Rome; and I fear that some recent obituaries of him compel me to add a few corrective remarks which are, unfortunately, demanded in the interests of scientific accuracy.

He was born in 1854, and studied medicine and then zoology in Pavia, Messina, and Germany; was appointed professor of zoology at Catania and then of comparative anatomy at Rome; and became a senator some years later. He was an enthusiastic worker on various zoological and parasitological subjects, and published, chiefly in collaboration with others, many finely illustrated monographs. Unfortunately, he seems to have been often engaged in fierce dissensions over priority with his colleagues and others (including myself); and I have publications or letters or both against him from E. Parona (Milan, 1887–8), S. Calandruccio (Catania and Rome, 1900–1), C. Ferni (Sassari, 1919–20), D. Carazzi (Florence, 1921–2), G. Cremonese (Rome, 1921), and Robert Koch (1901). For example, Dr. Calandruccio, in an article published in *The Journal of Tropical Medicine*, July 1, 1901, made many complaints of Grassi, with whom he had long been working in Catania, and gave specific examples. Thus, Calandruccio says that he himself found the *Filaria recondita* of the dog in ticks, but that Grassi published a résumé with his own name as collaborator; and then used similar devices with regard to Calandruccio's researches on *Ascaris lumbricoides* and *Trichocephalus dispar*. Calandruccio did most of the work on

Termites and the important transformation of Leptocephalids into Eels, costing him seven years of labour and 6,000 francs in money; yet the works appeared in their joint names, and it was Grassi who received a medal for them from the Royal Society in 1896. Calandruccio complained of this in a memorial to that Society dated November 26, 1901. G. Low completed Manson's cycle of the *Filaria bancrofti* in mosquitoes by finding the embryos in the insect's proboscis, but Grassi immediately wrote a long article pretending in effect that he had already found the same thing (see *British Medical Journal*, November 3, 1900, and *Lancet*, September 13, 1902, p. 775). But his efforts in connection with malaria and mosquitoes were the most remarkable, and deserve some accurate analysis.

In May 1895 I had commenced in India a formal investigation of the hypotheses of Manson and Laveran that the parasites of malaria may be carried by mosquitoes, and I published some early papers on the work. There being no precedents for such a research and no information available regarding Indian mosquitoes, I was obliged to investigate everything, including the technique, for myself; and there was nothing to guide me as to the species of mosquito concerned or the appearance or position of the minute *Plasmodia* within it. After endless failures for more than two years with hundreds of *Culex* and *Stegomyia*, I at last succeeded in growing one of the human malaria-parasites, *P. falciparum*, in two "dappled-winged" mosquitoes, easily seen afterwards to have been *Anopheles*, probably *stephensi* (August 20 and 21, 1897). These extremely fortunate observations gave us the required clues as to the form and position of the parasites in mosquitoes and as to the species of the carrier of *P. falciparum*; and all that has been done on the subject since then has been an easy and straightforward consequence of this fundamental discovery. It was published, with drawings and comments by P. Manson and others to whom my specimens had been sent, in (1) *The British Medical Journal* for December 18, 1897. A month later, just after I had found the same objects again and expected to have the whole mosquito-cycle of this human *Plasmodium* cleared up in a few weeks, I was suddenly ordered away—see (2) *Ibid.*, February 26, 1898. Five months later, in February 1898, I was able to resume the research in Calcutta, but owing to the plague scare was forced to work mostly with the malaria-parasite of birds called *Proteosoma*; and in six months unravelled the whole of *its* life-cycle in *Culex fatigans*. In (3) *The British Medical Journal* for June 18, 1898, Manson published my first results, sent him by letter, with drawings and diagrams of the mosquito-cycle, and with acceptances of my work by Laveran (the discoverer of the malaria parasites), Nuttall, and Metchnikoff, all of whom had seen my specimens. Simultaneously, the same work was described by me in (4) a *Report on the Cultivation of Proteosoma, Labbé, in Grey Mosquitoes*, to the Government of India, dated May 21, with full details of technique and of many crucial experiments, and with eight large plates, many copies of this book being issued by me from Calcutta before the end of June 1898 to many experts in various parts of the world; and Manson forwarded other copies to others, including Italians. Early next month (July) I found the sporozoids of the parasites actually in the salivary glands of the mosquitoes—thus suggesting the wonderful result that the malarial infection is caused by the *bites* of the infected insects. On July 6 I wrote to Manson my conclusion, that " Malaria is conveyed from a diseased person or bird to a healthy one by the proper species of mosquito, and is inoculated by its bite "—see my *Memoirs* (Murray, 1923) p. 299. On July 9, 1898, this was experimentally proved to be the case by five healthy birds having become infected by the bites of infected mosquitoes; and in the next few weeks many more healthy birds were infected in the same way under crucial conditions—thus confirming the result of July 9, which had completely elucidated the mosquito-cycle of the parasites. On or before July 25, in addition to sending many letters and specimens, I telegraphed this information to Manson from Calcutta (*Memoirs*, p. 305); and on July 28, 1898, Manson gave a complete account of my researches, including the infection of healthy birds, at the meeting of the British Medical Association in Edinburgh, before a large and enthusiastic audience, amongst whom were Dr. William Osler of Baltimore, and Prof. Raphael Blanchard of Paris, and other distinguished men. A resolution of congratulation was passed at the meeting and was sent to me; and Manson's address was published in (5) *The Lancet*, August 20, *The Journal of Tropical Medicine* for August, and *The British Medical Journal*, September 24, 1898, with many of my drawings, including one of the sporozoids in the salivary glands of mosquitoes (in the last, page 852). On August 13, 1898, my malaria work was again almost entirely interrupted, just when I wished to extend my *Proteosoma* results to the human parasites, by the Indian authorities, who sent me away to Assam in order to undertake laborious studies there on kala-azar, quite a different subject; and I left India in February next year.

From May 1895 to July 1898, therefore, I had obtained the important results which may be summarised as follows:

I had always failed to grow the human *Plasmodia* in many species of mosquitoes of the genera *Culex* and *Stegomyia*—except in one doubtful case (2).

In 1897 I had succeeded in growing *P. falciparum* in two kinds of "dappled-winged" mosquitoes, afterwards recognised to be *Anopheles*.

In 1898, up to July, I had discovered the whole life-cycle of *Proteosoma* (*Plasmodium danilewskyi*) of birds in *Culex fatigans*, including the route of infection.

All this work was fully published, with technique and illustrations, in five papers from December 18, 1897, to July 28, 1898, the last paper (5) being issued in print in the following August and September.

The mosquito-cycle of *Proteosoma* was the first metaxenous life-cycle in a second host ever established for any protozoal parasites; and this discovery of it has led to a wide reorganisation of the zoology of these minute animals, and holds zoological priority over all subsequent discoveries of similar life-histories in allied species of organisms. A very important step in the general cycle was, however, discovered by Simond and MacCallum in 1897 independently of me, in the case of *P. falciparum*.

At the end of July 1898 the following work remained to be done:

1. To complete the mosquito-cycle for all three human *Plasmodia*, already commenced by me for *P. falciparum* in 1897. Owing to zoological similarity this cycle was sure to be closely similar to that of *Proteosoma*. It has proved to be exactly the same.
2. To find the carriers of the human parasites in all malarious countries by my methods.
3. To ascertain the habits of those carriers everywhere, and the best means for reducing them.

All these tasks were now rendered easy by my Report (4); but, as there was no scientific literature on Indian mosquitoes, I was obliged to give fanciful temporary names to the principal genera studied by me, such as Grey Mosquitoes (*Culex*), Brindled Mosquitoes (*Stegomyia*), and Dappled-Winged Mosquitoes (*Anopheles*); and I relied on future work for identification of these. European mosquitoes (gnats) were much better known; and in 1896, just before the dates under consideration, E. Ficalbi had published an excellent work on the *Culicidæ Europea* (Florence, 1896), which was of immense help (seldom acknowledged) to workers in Europe, but of which I never heard at the time, much to my loss. I should add that from beginning to end of this Indian work I was practically a solitary amateur. My nomenclature for the mosquito-cycle was also tentative until next year (*Nature*, August 3, 1899).

The first confirmation of my *Proteosoma* studies was obtained by Robert Koch in Italy and Germany during the latter half of 1898. He had received my Report (4) and made ample and honourable acknowledgments in his paper (*Zeitschr. f. Hygiene*, Bd. xxxii, 1899).

The first Italian paper on the subject subsequent to my work of 1897 and 1898 was one by G. B. Grassi called *Rapporti tra la malaria e peculiari insetti*, etc.—*Nota preliminare*. It was published (1) in the *Rendiconti della R. Accad. dei Lincei*, vol. vii, pp. 163–72, among the "communicazioni pervenute all' Accademia prima de 2 ottobre 1898," and almost simultaneously in (2) the *Policlinico*, Rome, October 1, 1898, p. 469, but with several curious changes, one of which quite alters the final result. Now (1) is undated, but (2) is dated at the end "29 settembre, 1898." In his next paper (3), however, which is another *Nota preliminare* published five weeks later (*Lincei*, vol. vii, pp. 234–40, seduta del 6 novembre 1898), he says on page 236 that his first note (1) was communicated to that academy also on "29 settembre," the same date as (1) ! Quite recently (*Nature*, March 1, 1924, p. 304), he has declared, however, that (2) was the *second edition* of (1)—so that he sent in for publication two editions of the same paper, with a vital modification, on the same date, September 29, 1898 ! This modification is as follows : in (2) he infers definitely that "*Culex penicillaris* and *Anopheles claviger*, or at least *Culex penicillaris* and perhaps also *Culex malariæ*" (*vexans*) are the carriers of malaria (p. 476) ; but in (1) on page 171, this conclusion is not to be found, so that the reader may infer anything he pleases from Grassi's opening studies. An unkind critic might suggest that the two versions were sent in simultaneously in order to enable the author subsequently to lodge a claim for priority on the strength of the version which ultimately proved to be nearest the truth. But Grassi's next note (3) confirms (2) ; while, unfortunately, (1) ultimately proved to be nearest the truth.

Still more unfortunately both versions were merely conjectural and quite inconclusive, if not quite worthless. In both of them (paragraph 2), as well as on page 4 of his *Studi di uno zoologo sulla malaria*, published two years later (June 1900), he declares that he commenced work on July 15, 1898, onwards. What exactly did he attempt ? He visited malarious areas near Rome in the hope of finding some "correlation" between the prevalence of the disease and of various species of mosquitoes there, by what the mathematicians call "random sampling." He was not a mathematician, or else he would have understood (as I had done) that this process would have required years, not weeks, even to approach success. But he was not deterred by such mean doubts ; he does not condescend to give details as to dates and itineraries ; but in two months he was ready with both "editions" of his papers

(1 and 2), sent in on September 29. What exactly did he find? Out of three species of mosquitoes which he thought were guilty, two were subsequently proved innocent; and out of seven species which he thought were innocent, two were subsequently proved guilty.

I regret I have other criticisms to make of Grassi's first papers (1 and 2). When he started work on July 15 all my discoveries, including the infection of healthy birds on July 9, had been already achieved. My first two papers (1 and 2) had been published months previously; and Manson's first paper recording the proof of the mosquito theory and its acceptance by him, Nuttall, Laveran, and Metchnikoff, namely (3) of June 18, 1898, had been issued for nearly a month. But there is no mention of all this in Grassi's papers (1 and 2) sent in more than two months later (September 29). All he does is to refer vaguely in his (1 and 2, paragraph 4) to the malaria of birds, and more explicitly so in an interpolated passage in (2, paragraph 1); but in neither case does he mention my name or Manson's, nor give the smallest reference to the literature which would enable a reader to study the subject for himself; and such a reader would naturally attribute everything to Grassi. Yet on or about that date (September 29) he had actually received Manson's full address (5)! This is stated by *himself* on page 235 of his next note (3), (*Lincei*, November 6, already mentioned), where he says that Manson's address, published in *The British Medical Journal* on September 24, " pervennero a Roma alla fine di settembre." (It had been published in the *Lancet* five weeks previously!) Possibly it was the receipt of this publication which forced him to send off both " editions " of his first note on September 29—hurriedly! In this same later note (3) of his he also mentions (p. 235) having received from Manson some of my *Proteosoma* mosquitoes (*Culex*), and, be it noted, a " Memoria del Ross " which could have been none other than my *Proteosoma* Report (4) itself, giving full details of my work. Exactly when this reached him I cannot say. Copies were issued from India at the end of June; and A. Bignami mentions it and Manson's address (5), as familiar things in his first paper in the *Bull. R. Accad. Medica d. Roma*, November 15, 1898 (translation in *Lancet*, December 3 and 10, pp. 1462 and 1542). As in this case, Grassi often omits dates and adequate reference to previous literature. For instance, I think he never mentions Manson's article (3) which preceded all his efforts; and he mentioned my papers (1 and 2) later only to falsify them shamelessly. It is my conviction that the Roman observers had seen, read, and studied all the five papers by Manson and myself described above, *immediately they had appeared* (see remark by Dr. Charles quoted presently). In any case, my papers hold complete priority of publication.

Yet afterwards (*Studi*, 1900) Grassi had the assurance to declare that these loose speculations of his had definitely discovered the "*Anopheles* malariferi," not only in Italy, but by implication throughout the world! "Io arrivai agli *Anopheles* malariferi indipendentemente da Ross," he exclaimed on p. 31, and added that my researches on the malaria parasites of birds were published almost contemporaneously with his first preliminary note (October 1, 1898)! This pure invention has deceived many persons who write on the subject but are ignorant of sound scientific methods or have never studied the original literature; and Grassi later received several monetary prizes, as well as honours, for his discovery, including one of 15,000 lire from the Academy of Science of Turin, on January 24, 1904. What he really discovered was my previous work and the generic name of my "dappled-winged" mosquitoes. But when he published his romance in 1900 he was ignorant of Charles's letters to me, to be mentioned presently. Except for these he may have succeeded in persuading many of his readers that his work was original—which was not the case.

The truth is that two species of "*Anopheles* malariferi" were found by me in India in August and September 1897, nearly a year before Grassi even began his work. The *Anopheles* malariferi for Italy (only) were discovered at the end of 1898 and early in 1899, not by Grassi, but chiefly by two medical men, Drs. A. Bignami and G. Bastianelli, with full knowledge of my technique and my previous results. The facts are detailed in my *Memoirs*. Before November 8, 1898, Manson sent one of my specimens to Bignami and another to Dr. T. Edmonston Charles, who was then in Rome and who wrote me a series of letters beginning November 4 and describing in detail how these gentlemen and Grassi were attempting to follow my work—they did not know the contents of these letters until I published them in April 1901. In the first letter he wrote: "It has been a cause of surprise to me how very closely they have followed all that you have done, and how fluently they talk regarding details of your work." Bignami had long rightly conjectured (as did A. F. A. King in 1883) that malaria may be caused by the bites of marsh mosquitoes and had tried thus to infect healthy men in Rome with insects bred in the marshes. On September 26, however, in the light of my Report (4) or of Manson's address (5), he varied this procedure by using possibly-infected adult mosquitoes brought from a malarious locality; and the patient was found infected on November 3. This was the first real Italian success, and confirmed my infection of birds in July. Three species of mosquito, *C. vexans*, *C. peni*-

cillaris, and *A. maculipennis* were used, and it was not certain which had carried the germ. On November 25 Charles wrote "I went to Professor Grassi's laboratory and showed him one of your preparations. . . . He seemed much pleased, and I understood him to say he had just found it in a preparation of his own." [Frankly, I do not believe it.] In this and in his previous letter Charles told me that they thought my "dappled-winged" mosquito was *A. claviger* (*vel maculipennis*) —they must have recognised it, possibly weeks or months previously, from my description of the wings and eggs in my first paper (1). There was now no further difficulty. At the end of November, with full knowledge of my technique, my figures, and my descriptions, they succeeded in cultivating *P. falciparum* in another "dappled-winged" mosquito, *A. claviger*, exactly as I had done fifteen months previously in India; and then they completed the mosquito-cycle for that parasite and found it to be exactly the same as that of *Proteosoma*, which Manson and I had described four to five months previously. There can be no doubt that they had recognised the genus of my "dappled-winged" mosquitoes, for *they themselves say so* in their very first paper which records this success (*Atti d. Lincei, seduta del* 4 December 1898). The only new result, not expected by me, was obtained a little later by Bignami and Bastianelli—that the tertian and quartan parasites in Italy also grow in *Anopheles* (*Lancet*, January 13, 1900). It was these authors, and not Grassi, who worked out the minute cytology of the mosquito-cycle (*Bull. d. R. Accad. Medica di Roma*, April 19, 1899)—a subject which I had been obliged to leave untouched; and we owe to *them* the experimental infection of some subsequent cases by mosquitoes.

How easy all this was after my original publications may be inferred from the fact that when I was able to resume malaria work in August 1899 H. E. Annett, E. E. Austen, and myself found all three species of the human *Plasmodia* in two "dappled-winged" species of mosquitoes, *A. costalis* and *A. funestus*, in Sierra Leone, *within two weeks!* And this would have been done equally well if the Italian work had never been attempted. We also outlined the habits of the insects in Sierra Leone, and the methods of prevention. Subsequently, precisely the same work has been easily done in many parts of the world. In science, as in other things, *ce n'est que le premier pas qui coûte.*

Facile as it was, the Roman work would have been better if the writers had always made due acknowledgments of previous work. Laveran, Golgi, Canalis, Mannaberg, and others had already complained of Roman plagiarisms; and Manson and myself were now treated in the same way. True, Bignami and Bastianelli soon admitted their obligations—

though not always accurately ; but Grassi was beyond publishable criticism in this respect. By twisting the facts and by omitting dates and full references to previous writings or by misrepresenting them, he tries to attribute everything to himself, and then accuses his victims of the very tricks which he himself is employing against them. His later book *Studi di uno zoologo* (magnificently illustrated) is perhaps the greatest masterpiece ever written in the art of falsifying scientific history. Thirty-one pages of it, besides isolated passages, are occupied with gratuitous abuse of R. Koch and myself ; and yet the book is little else but a compilation of our labours and those of Bignami and Bastianelli—all attributed by the author to himself. His dialectic is exactly that of the "informers" of ancient Rome described by Tacitus : every sentence contains a truth and a falsity so closely woven together that the victim must spend pages in extricating and exposing them ; and, to confuse the reader still more, the history is not consecutive, nor the bibliography complete. In 1903 he published another attack (among several) upon me, in a small book (*Rancati*, Milan). It purported to contain translations of important papers of mine ; but fundamental passages in these are omitted without notice ! It also attacked Lord Lister, who, like Laveran, Manson, Koch, and others, supported me (see my *Memoirs*). With another artifice worthy of ancient Rome, both this and the previous book were dedicated to Manson ; but Manson publicly repudiated the dedication of the later effusion (*Lancet* and *British Medical Journal*, March 28, 1903). Since then Grassi continued to pursue me with greater originality than he ever employed against the "*Anopheles* malariferi" ; and he did so with very similar stratagems to those of which Calandruccio and others had complained. In my recent *Memoirs* I ventured to expose some but by no means all of these subtleties, and even to accuse him frankly of having attempted scientific piracy. Thereupon he threatened legal proceedings ; but his courage failed him, and he relieved his feelings instead by two more of his usual attacks, in *Nature* of March 1924—to which I refused to reply. Really, he played no leading part in the solution of the malaria problem, even in Italy, except the identification of mosquitoes. Many of his claims were as spurious as his "random sampling"—for instance, when he pretended to have proved in a few weeks during the winter of 1898–9 that the whole genus *Culex* is negative to human malaria, a conclusion which could not be scientifically established without prolonged research at all seasons, and in all countries, but which he hastily derived from my previous writings (without acknowledgment). How little he really knew about mosquitoes even in 1901 was shown by his condemnation of me for presuming to judge their age—often an easy task (*Memoirs*, p. 412). I have not studied his other works, and never met him; but from my own experiences must fully endorse the criticisms of other sufferers regarding his extreme dexterity in matters of scientific history—at least. Whether any of his discoveries were really original I cannot say—but beg leave to doubt it.

As regards myself, I forgave him long ago—and he was mild compared with those who blamed me subsequently for suggesting the possibility of "mosquito-reduction" in malarious towns. But I confess that I do not like any trace of plagiarism in science, the honour of which must be jealously guarded. As a *science* parasitology is a comparatively small affair, but as a *business* it concerns the welfare of millions of men, born or unborn, and of their crops and cattle, and should be actively encouraged. Those who study it, however, receive little or no thanks: it is, therefore, an infamy that they and their work should also be subjected to years of abuse by people who try to rob them of the small credit which they have rightly earned. They have little means of defence: if they reply to the pirates they are accused of boasting; and if they do not reply the case goes against them by default. They cannot take their cases into the law-courts (as I have ascertained). Learned societies will not help them, or cannot do so; and the writers of textbooks seldom trouble to examine the original literature. All this has a pernicious effect on the advancement of a most valuable branch of science, and many original workers in it must regret (as I do) the day when they first touched it. Their only way to check the evil (which is frequent) is to expose it thoroughly when they can; and it is their duty to do so.

References to all the pertinent literature will be found in my *Memoirs* and also in greater detail in my Nobel Lecture (*Journ. R. Army Medical Corps*, April-June 1905).

ESSAY-REVIEWS

ARE THE CONTINENTS ADRIFT? By G. W. TYRRELL, A.R.C.Sc., Ph.D. Being a Review of **The Origin of Continents and Oceans**, by A. WEGENER, Professor of Oceanography and Meteorology in the University of Graz. Translated from the Third German Edition by J. G. A. SKERL, M.Sc., with an Introduction by J. W. EVANS, C.B.E., F.R.S. [Pp. xx + 212, with 44 figures]. (London: Methuen & Co., 1925. Price 10s. 6d. net.)

GEOLOGISTS have long been familiar with the idea of earth movements in the vertical direction, ranging from displacement along faults to the uplift or subsidence of areas of continental dimensions. More recently they became accustomed to the idea of horizontal displacement, leading to lateral movement along tear-faults, and to the great recumbent folds and thrust-planes of the Alpine type of mountain structure. It has been left, however, to Prof. A. Wegener to elaborate the idea of the lateral movement of continents over distances amounting to thousands of miles, and of the formation of oceans, such as the Atlantic, as by-products of this process. Wegener's paper announcing the idea was published in 1912; and his book, *Die Enstehung der Kontinente und Oceane*, was first published in 1915, and reached a third edition in 1922. Although the work had attracted attention and aroused increasing controversy on the Continent during this period, for obvious reasons it was only after the War that it was noticed in this country and in America, where Wegener's hypothesis, as usual with revolutionary notions of this sort, has been accorded enthusiastic support, and, at the same time, has engendered violent opposition. It is certain now to receive renewed attention, as the third edition of Wegener's book has been translated into English by Mr. J. G. A. Skerl of the University of Liverpool, and has been published with an introduction by Dr. J. W. Evans, C.B.E., F.R.S., the President of the Geological Society.

It may be said, in passing, that Mr. Skerl has done his work well, although in places the language is rather stilted and betrays more than a trace of the original tongue. Wegener's German is none of the clearest, and a little haziness in some passages may be excused on that account. The translation has been revised by Dr. Evans, and also submitted to Prof. Wegener. It may therefore be taken as an accurate and authoritative version of his hypothesis.

The discovery that Wegener had been more or less anticipated, and that his great idea had been foreshadowed in earlier writings, was perhaps inevitable. The American, F. B. Taylor, especially, had suggested views akin to Wegener's.[1] Prof. R. A. Daly says: "For the greater part the discussion [of the hypothesis of continental sliding] has centred around Wegener's book, but it must not be overlooked that Taylor has the distinction of being the first to formulate clearly and at the same time comprehensively the root idea of the horizontal displacement of continents, coupled with concrete illustrations of its meaning for dynamical and structural geology."[2] As early as 1842 W. W. Mather, in a report on the geology of New York State, clearly foreshadowed the doctrine of the lateral movement of large land masses, as has been pointed out in another review (SCIENCE PROGRESS, July 1925, p. 146). But, as Lowell says somewhere, the credit for an idea rests with him "who utters it clearest and best"; and, since Taylor and Wegener both independently conceived the same or closely similar idea at approximately the same time, and elaborated it in some detail, we ought perhaps to speak of the Taylor-Wegener hypothesis, as Prof. R. A. Daly has already done.

The hypothesis seems to have been suggested to Wegener by a well-known geographical observation, the similarity in outline between the eastern coast of South America and the western coast of Africa. If brought together they would fit like two pieces of a jig-saw puzzle. Lake has suggested that the fit is by no means exact, especially if it is carried out on a globe instead of a map; but a certain freedom must be allowed on account of coastal changes subsequent to the supposed rifting. When the idea of rifting is carried farther north, it is found that Spain has to be rotated through 90 degrees, and Newfoundland through 30 degrees, in order to make an approximate fit with the coast lines on the opposite side of the Atlantic; and this has also been advanced as an objection to the hypothesis. But if lateral movement is conceded, it is too much to expect that the drifting masses should always remain parallel to themselves, and there is no reason why rotation should not take place in more or less detached fragments. Much use is made by Wegener and his supporters of analogy with a broken ice-floe, the fragments of which drift apart; and it must be admitted that the shape and arrangement of the Arctic islands north of Canada, and of the Spitzbergen archipelago, very clearly suggest rifting and drifting of land masses in a way similar to broken ice.

While there is often a close approximation to geographical

[1] *Bull. Geol. Soc. America*, **21**, 1910, p. 179.

[2] *Amer. Journ. Sci.*, **5**, 1923, p. 365.

fitting between opposite coasts, there is also frequently a striking geological correspondence. Not only do the shapes of the severed pieces correspond, but also their geological grain. It would take much too long to give the evidence, which, however, is well known to geologists, that geological features on the European and African side of the Atlantic are paralleled on the American side. Some of the details of the fit have been criticised, but the general fact is unquestionable. Washington, for example, says that the petrographic evidence is adverse to it (SCIENCE PROGRESS, April 1924, p. 538).

In order to account for the possibility of the lateral movement of continents Wegener conceives them as large, thin cakes of *sial* (Suess's name for the uppermost and lightest layer of the earth's crust consisting largely of rocks of granitic composition) floating in the heavier *sima* (Suess's name for the layer of ferro-magnesian composition underlying the sial, and, as gravity observations show, probably forming the oceanic floors). The drifting of the continents is thus essentially the movement of sial blocks through an ocean of sima which may be regarded as an excessively viscous liquid. The segregation of the once universal sial layer into the present continental masses cannot be fully discussed here. Wegener believes it to be due to successive mountain foldings, a process resembling, as he says, the folding of a round paper lantern, opening on the one side and folding up on the other.

Evidence for the two layers of the earth's crust is found in the distribution of levels over the land surfaces and the ocean floors. The frequencies are grouped about two well-defined values, 100 metres above sea-level, and 4,700 metres below sea-level. If there had been a single initial level in the crust, and the present variations had arisen by simple elevation and depression, it would have been expected that the curve of frequencies would have had but a single peak, whereas it has two at the points above stated. These are believed to represent two initial levels on which the subsequent elevations and depressions have been superposed. They represent the initial levels of the original layers of sial and sima respectively.

Wegener, then, imagines the thin surface shell of sial ruptured and contracted into a primitive unitary continental mass centred around Africa as a nucleus (Pangæa), leaving a vast ocean floored with the underlying sima. South America adjoined Africa, and North America was close to Europe. Similarly Antarctica, Australia, and a vaster India, were in contact with South Africa. Pangæa was intact at the beginning of the Mesozoic, but, in the course of the succeeding periods, it split into the various detached blocks which became the present continents and larger land units. These drifted away in all directions, Australia eastwards, Antarctica to the south, and India to the north-east. The widening rift separating the Americas from Africa and Europe presently became the Atlantic Ocean. India originally formed a large continental tract partly covered by shallow seas, connecting Africa with the primitive Asian continent. The intervening region of weak, shallow-water sediments is believed to have been folded up by the gradual approach of the unyielding mass of Peninsular India towards Asia, and now forms the broad folded zone of the Himalaya and the Central Asian chains. By the westward drift of the two Americas through the stiffened sima of the Pacific, their anterior margins were crumpled to form the great mountain ranges stretching from Alaska to Antarctica. Lagging masses became festoons of islands (the Antilles, etc.), and as all the continental masses are now conceived to have a westward drift, the Asiatic and Australian festoons (Japan, the East Indies, New Zealand) are thus explained.

Such, then, in the baldest outline, is Wegener's hypothesis. It must be said that Wegener is not convincing as to the earth forces available for the production of these mighty mass movements. Jeffreys, indeed, has stated that the known effective forces tending to move the continents are one hundred million million times too small! But geologists will have Huxley's mathematical mill too much in mind to pay much heed to this latest physico-mathematical *ipse dixit* upon a geological problem; and if adequate geological proof of continental drift is forthcoming, geologists will believe in it despite any assertion of its physical or mathematical impossibility.

The most unequivocal success of Wegener's hypothesis is in the explanation of the great Mesozoic continent of Gondwanaland, with its widespread glaciation, freshwater sediments, and *Glossopteris* flora, which are to be found in such widely separated parts of the earth as the Falkland Islands, Brazil, Antarctica, South Africa, Peninsular India, and Australia. On this basis palæogeographers have assumed an enormous southern continent in Mesozoic times; and, if its present remnants have always been where they are now, the disappearance of the connecting parts covering the present sites of the South Atlantic and Indian Oceans is very hard to explain. If, however, Gondwanaland was originally only a moderately large continent centred in the south temperate zone about the present site of South Africa, its distinctive features, especially its glaciation, become much more comprehensible, and the difficulties concerning the oceanic links are entirely avoided. A. du Toit, who has recently written an elaborate review of the Carboniferous glaciation of South Africa, is a notable convert to Wegener's views in this respect (SCIENCE PROGRESS, April

1923, p. 553). On the other hand, Wegener is much less successful in explaining the Pleistocene glaciation of the Northern Hemisphere by the assumption that North America and Europe were still in contact until after the Glacial Period ; and Prof. A. P. Coleman has little difficulty in riddling this part of the hypothesis (SCIENCE PROGRESS, January 1925, p. 389).

The necessity for explaining the alternation of polar and equatorial conditions in the same land area has led Wegener to a whole-hearted acceptance of the doctrine of polar migration. Thus, the glaciation of Wegener's Pangæa in Carboniferous-Permian times necessitates the presence of the South Pole in the neighbourhood of South Africa. This, no doubt, will lead to a revival of interest in the question of *Polflucht*, for which L. Cotton has recently entered a powerful plea (SCIENCE PROGRESS, July 1924, p. 32).

According to Wegener, the westerly drift of land masses is still in progress. Thus, the differences between the longitude determinations of the Sabine Expedition of 1823, the German North Polar Expedition of 1870, and the Danish Expedition of 1906–8, in Greenland, suggest a westerly drift of 15 metres a year for that country. But early determinations of longitude and latitude in outlying regions are notoriously unreliable. Col. Sir C. Close, the Director of the Ordnance Survey, has critically examined the evidence (*Geog. Journ.*, February 1924) and finds the westerly drift of Greenland unproved, since the differences between the earlier and later determinations of longitude fall within the permissible limits of error. Confirmation or rejection of Wegener's speculation, so far as Greenland is concerned, must await another wireless determination of the longitude of Gotthaab after a suitable interval of time. It is obvious that this test is capable of application to other points.

The Taylor-Wegener hypothesis of continental sliding will remain *sub judice* for many years ; but whether it gains ultimate acceptance, or falls under the weight of adverse facts, it will have been of great service to geological science in its quickening of interest in geotectonic matters—a quickening which has already shown itself in a great revival of speculation and research on the origin and relations of continents, oceans, and mountains, and on the general structure of the crust. The sympathetic introduction which Dr. J. W. Evans contributes to the English translation of Wegener's book shows that the hypothesis of continental drift must be seriously reckoned with, and that it has already influenced British workers in these fascinating earth problems.

THE BORDERS OF BIOLOGY: MODERN VIEWS ON LIFE AND MIND.

By J. H. Woodger. Being a Review of **Living Organisms**, by E. S. Goodrich, F.R.S. [Pp. 200.] (Oxford: at the Clarendon Press. Price 6*s*. net.)

Although the statement that much of the fascination and many of the difficulties of biology spring from the fact that the observer and student of living things is himself alive, may seem a truism, it is nevertheless one of which the implications are often overlooked, misunderstood, or forgotten.

If biology is the study of living things, then it might seem that, since " mind " or " consciousness " is an attribute of man, then psychology must be a branch of biology. But a very little reflection will show, not only that this is not the case, but that very serious difficulties must, and in current biological literature frequently do, follow the failure to understand the fundamental differences between these two provinces of knowledge.

The material of all knowledge is " givenness "—that which is presented to the conscious subject; but this material is not homogeneous. Not only do its constituents differ among themselves (otherwise there would be no knowledge at all) but certain of them differ as a whole from the rest in being " objectified," *i.e.* referred to external objects which can be regarded as existing independently of the perceiving subject. It is these objects (although, of course, known only in so far as they *are* presented to consciousness) which form the subject-matter of natural science. Psychology, on the other hand, is concerned not only with these contents *as* presentations, but with all the rest of givenness, including the subject himself, for the " I knowing " becomes, in self-conscious reflection, the " Me known." It is thus to be noted that psychology, at least at the outset, involves no such dualism of mind and matter as confronts natural science when the latter assumes its objects to exist externally and independently of the mind.

Natural science, in thus completely " objectifying " its objects, exposes itself to the dangers of forgetting the real nature of its knowledge of them. In ascribing external reality to its perceptual objects, it slips easily into the errors attending the similar " reification " of conceptual ones. Its purely objective attitude disqualifies it from making pronouncements about mind. But when once natural science has launched into realism all is plain sailing: mind seems never to trouble it again, and many of its votaries are never conscious of having made such an assumption as is involved in realism at all. We are literally all *born* realists—to be so is in fact, from the biological standpoint, a condition of survival. To be anything else is an intellectual perversion, resulting from life in a comparatively sheltered environment! It is for this reason that, in the history of thought, Aristotle preceded Descartes, and for this reason too science is nothing but " trained and organised common sense." If more of the followers of Natural Science understood the real nature and limitations of common sense, even when " trained and organised," less energy would be expended on meaningless quarrels between the several branches of intellectual inquiry, and the members of the human family would be free to work together in harmony.

When we turn again to the psychological point of view we find that its difficulties begin when mental science attempts to transcend the limits of the individual mind. It knows and can study other minds only through those contents of consciousness which are objectified, since it is these that constitute the region of common experience, and form the only means of mutual understanding. Psychology is able to give no account of the origin of presentations ; they form its ultimate data : it cannot explain sensation.

From these considerations it would seem that psychology on the one hand, and biology, as a strictly natural science, on the other, would be well advised to remain rigidly within their respective spheres, as prescribed for them by the unfathomable and inexorable nature of things. This, however, they have never succeeded in doing consistently, and for the very reason that we noted at the outset—that man, knowing himself intuitively as a thinking, feeling, and willing subject, has also discovered that he inhabits an organism, and the riddle presented by these two aspects of his existence has never failed to be of absorbing interest to him.

It is true, perhaps, that these considerations need never disturb the cytologist, the systematist, or the embryologist ; but as soon as we become biologists—students of living things in general—we cannot avoid them. Our own curiosity drives us to these dangerous borders of biology, and if we are writers of books for the instruction of others in the achievements of that science our readers will expect some pronouncement on these most enthralling topics. Nor are they of merely academic interest, for we shall find that these paths lead, if we follow them far enough, to the most important things in life, to conduct—morality and religion ; in the past they have led to the cross of martyrdom itself. Even quite mundane things of daily life are touched, according to the side we take in the interminable war between physiology and psychology—witness the present unfortunate conflict between the psychological and purely neurological attitudes towards mental disease ; unfortunate because suffering humanity must wait while those who help it quarrel.

In approaching these dangerous borders of Biology it is evident that we must do so in full consciousness of the fact and with a clear understanding of the nature of the pitfalls that await us. But what guide have we? What court of appeal exists that can decide the issues between psychology and natural science?

There is such a guide, but it is one to which natural science is often reluctant to appeal. The word "philosophy" is too often synonymous with "nonsense" to the student of nature, who, when called upon to recognise precise but perfectly necessary distinctions which may be unfamiliar to him, is too apt to dismiss them as "metaphysical." In fact, the very region of knowledge we are discussing is often turned from in disgust and dubbed "the sloughs of metaphysics" by those who have made up their minds, and taken a metaphysical decision without being aware of it.

There is one branch of philosophy, however, which merits a more sympathetic consideration; it has been variously called theory of knowledge, critical philosophy, or epistemology. It seeks to determine the nature and limits of knowledge—information of which we are surely often in need. This alone is able to help us to avoid that unconscious sliding from positive science into metaphysical assumptions which so often vitiates discussion. It will teach us to use words without ambiguity, to employ such concepts as cause and effect, necessity, teleology, etc., correctly, and to understand the meaning and possibilities of "explanation."

This is not the place in which to pursue further the important results for science of the inquiries of critical philosophy. Some of the principles underlying the approach to the present problem have already been indicated. Let us now turn to the actual conflict itself and see what its fruits have been.

Mind seems always to have been a thorn in the flesh to physiologists: it has seemed to them to present obstacles to their dream of a "billiard-ball" universe. They have, for the most part, been content either to ignore it, or to dismiss it as an "epiphenomenon," a collateral product of the working of the nervous system. T. H. Huxley, in one of his letters, remarked that: "The generation of feeling is the specific reaction of a particle of the sensorium when stimulated, just as contraction, etc., is the specific reaction of a muscular fibre when stimulated by a nerve." The same notion underlies the statement of Sir William Bayliss in an article on recent advances in physiology for the general reader: "The position of consciousness in physiological processes is by no means clear. While it may be held that the province of physiology is to investigate what can be made out experimentally in the nervous centres, it does not seem impossible that consciousness may ultimately fall into place as one of the functions of nervous tissue."[1] In this statement we have a clear declaration of the true position of natural science, but an inability to resist the temptation to reach beyond it, owing to a failure to understand the peculiar nature of psychology.

Epiphenomenalism is always confronted with the epistemological difficulty that objects—neurones, molecules, etc.—are, in being known, themselves of the mind—the epiphenomenon, the collateral product ! Huxley himself knew this well enough, and yet, as Case has pointed out, he " reduces consciousness to a product of matter, and then matter to a phenomenon of consciousness."

A concession is made to psychology in the various forms of the well-known doctrine of psycho-physical parallelism. Here mind is not only admitted to exist, it is even allowed to have " laws " of its own, but it is prevented from being a nuisance to physiology by being considered as an invariable accompaniment of physical processes, but without any influence on them. The two processes go on independently, unaffected by one another but, for some inexplicable reason, always strictly parallel to one another. Parallelism especially finds favour with those who assert that non-interaction is proved by the claim that the energy output of the organism is approximately equal to the input. One important event in the history of science, which is of special interest from the methodological standpoint, should, however, give us pause in drawing this conclusion. The event referred to is that which followed the closer investigation of " Cavendish's bubble," and ultimately led to the discovery of argon. Before Rayleigh queried the accepted view it had long been known that the density of nitrogen, as determined from the atmospheric gas, was never quite the same as that reached by a study of the nitrogen liberated from its compounds. It was a brilliant achievement of Rayleigh to doubt the accepted explanation that this was merely the result of experimental error, to connect the fact with the bubble of gas found by Cavendish after the explosion of oxygen and nitrogen obtained from the air, and to suggest that the effect was due to the presence of unknown gases in the air. Weldon[2] has drawn attention to the moral—that something may always be overlooked if we are content to dismiss such discrepancies in approximations.

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[1] *Encyclopedia Britannica*, 12th edition, vol. 32, p. 100. In his *General Physiology*, in discussing Müller's Law, Bayliss makes the admission : "Why these nerve impulses, alike in themselves, give rise to such widely different sensations . . . is a matter beyond the scope of physiological analysis."

[2] In *Lectures on the Method of Science*. Edited by T. B. Strong, Oxford,

A third theory is that of interactionism, which is diametrically opposed to parallelism in recognising interaction between neural process and mental activity. It also admits a full recognition of the totally different nature of the two processes and of the apparent differences of complexity between them. Parallelism is forced to an appeal to our ignorance of the nervous system to account for the latter discrepancy.

It must be understood that, although these theories are held as *scientific* hypotheses, they all imply and ultimately rest upon *metaphysical* bases, even if this is not always remembered by their exponents. Epiphenomenalism is usually an outcome of materialism; parallelism is the logical consequence of the doctrines of Spinoza; and interactionism is consistent with realism, but does not escape the difficulties of dualism.

Parallelism seems to be the position adopted by Prof. E. S. Goodrich in his recent introductory book intended for the general reader. At the close of a thoroughly mechanistic exposition of modern evolutionary biology he adds a section on "Psychology and the Evolution of Intelligence." He begins by warning us not to "trespass into the region of philosophy" and not to confuse his mechanistic explanation with materialism—"a discredited system of philosophy which denies the existence of anything but the material or physical."[1] This is followed by what appears to be an exposition of psycho-physical parallelism: "We believe that to every mental process, whether of the 'highest' kind in the mind of man or of the 'lowest' in that of the most primitive organism, there corresponds some physico-chemical change. How intimately connected are the two sets of processes is a matter of common knowledge. The slightest disturbance or interruption in the metabolism of the brain, due to an injury, an anæsthetic, a poison, will have its echo in a disturbance of the mental activities." "So far as we know, neither the mental nor the metabolic processes can take place without the other. Yet, indissolubly bound together as they are, the one is certainly not the product of the other, nor can it interfere with the continuity of the other."

After a summary dismissal of materialism the warning regarding trespassing into philosophy seems to be forgotten, for there follows a declaration of the creed of the Spinozan metaphysical basis of parallelism. Body and mind are referred to as "two aspects of one and the same series of events," and as "two abstractions from the same fundamental reality." If what has been said about the method of science is remembered it will be evident that we cannot make such assertions as these from the standpoint of biology.

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[1] Mechanism *need not* be materialistic. It is possible to maintain it on methodological grounds, while leaving the philosophical question untouched.

The use of the word "echo" in the statement already quoted that "The slightest disturbance or interruption in the metabolism of the brain . . will have its echo in a disturbance of the mental activities" is perhaps rather unfortunate, for this at least *implies* a causal connection between the two, whereas if the two are aspects of one and the same series of events there can be no question of a causal connection between them. This statement also *suggests* that the physical processes in some way come first, otherwise we might equally say that the slightest disturbance of the mental activities will have its echo in a disturbance in the metabolism of the brain. A strict parallelist must admit this, and Professor Goodrich in effect does so when he writes (p. 175): "And the question, which is the more important in evolution—the mental or the physical series—really has no meaning, since one cannot happen without the other." The author is, therefore, perfectly consistent *within his system*, but the point is that the whole doctrine rests upon the original metaphysical assumption. That this *is* metaphysical, and not biological, should have been pointed out, lest the general reader be misled into supposing that it rests on empirical data and is the only possible point of view. The truth is that the alternative doctrine of interactionism has as much to be said for and against it as parallelism has. A little lower down (p. 176) it is clearly stated that the student of biology "should realise that the mental series of events lies outside the scope of natural science," but the reason for this is not explicitly stated, and the warning does not appear to be quite consistently followed, for in the succeeding pages many statements are made about mental processes and their evolution.

When we reach the problem of the evolution of intelligence and consciousness we find that parallelism enables many difficulties to be avoided. What appears to be a consequence of this doctrine, at least in its metaphysical form, is the belief known as Panpsychism, which asserts that *all* physical processes are accompanied by mental ones. Spinoza himself did not shrink from this conclusion, for he held that the "one fundamental reality" has two attributes—extension and mind—and that therefore everything that has extension also has mind.

We get some clue to Prof. Goodrich's standpoint on p. 175, where he says: "We know of no mind apart from body, and we have no right to assume that metabolic processes can occur without corresponding mental processes, however simple they may be." From this it would appear to follow that we have no right to assume that the secretion of mucus by a goblet-cell can occur without corresponding mental processes. Nor are we given any reason to suppose that we need stop at the vital, for vital processes are themselves regarded as physico-chemical ones, hence we must add that we have no right to assume that oxygen can combine with hydrogen without corresponding mental processes occurring. By these inevitable steps we are driven to the full acceptance of panpsychism.

It will be obvious how panpsychism smooths the path for the evolutionist. As the one fundamental reality evolved its attributes necessarily evolved too, the physical along with the psychical, and so the thorny question regarding the point at which mental activity entered does not arise. There is no question of mind evolving from something else: it exists from the beginning.

The problem next arises: Are these processes, which are called mental, conscious? It is clear that the panpsychist has two alternatives. Either they are conscious from the start, or they are unconscious at the lower levels and only become conscious at a late period. If they have been unconscious for immense periods and still are so in the vast majority of living things, then it is very difficult to justify the application to them of the term "mental." They would appear to be entirely meaningless and unnecessary, except in so far as they enable the evolutionist to overcome the difficulty mentioned in the preceding paragraph. But it is not clear why a thorough panpsychist should hesitate to adopt the former of the above two alternatives. For, since there is no interaction between mind and body, consciousness cannot have a directive rôle, and consciousness might just as well exist as not. We know, of course, that unconscious mental activities of even a very high order *do* take place in man, but they always have reference to past or future conscious life. The concept of the unconscious has in fact been invented to account for changes in consciousness which would otherwise be unintelligible; much as the concept of potential energy has been invented in physics. To one who does not embrace the panpsychist doctrine the attribution of consciousness to the inorganic will, of course, be utterly absurd. Inorganic things do not behave like organisms, and the concept is unnecessary. If, however, we could believe that all *organisms* were conscious we should be able to *understand* them in the fullest sense of the word. We understand our own actions because we believe ourselves to have willed them, and only in so far as we can regard other organisms as psycho-physical individuals can they be fully intelligible to us. A psychological fact of great importance in this connection is that consciousness is most acute when some new situation is to be met, some decision made. When new accomplishments have been slowly and painfully learnt in full consciousness, *e.g.* walking, skating, etc., they can finally be performed unconsciously, and consciousness is then free to solve other difficulties. This fact is often quoted against parallelism, and is itself suggestive of the directive importance of consciousness. It is clearly an advantage to us to be able to perform activities unconsciously, leaving attention free to deal with other things; but, if consciousness is a mere accompaniment of physical processes, this fact remains inexplicable. The truth is that parallelism never escapes the implications of materialism, in spite of the " two-aspects " assumption.

We must not fall into the error of supposing that if we knew all the physical processes which take place in the brain we should in the least understand *consciousness*. Even if we pass over all the complex intellectual processes, and consider such an apparently simple one as the pain experienced on the pricking of the skin with a pin—even if in such a case we had a complete account of all the physiological and physical occurrences involved, if the living brain were so accessible and so magnified as to enable us to observe the very molecules jostling one another in the nerve cells, even then we should know nothing of the pain *as such*. In the sense in which natural science uses the term we should not *know* pain at all; we cannot see it, smell it, hear it, touch it, much less weigh or measure it. We can only know pain in the psychological sense, *i.e.* by immediately experiencing it, and in that sense the navvy probably knows as much about pain as the most learned professor of physiology does. Prof. Goodrich admits this on p. 176.

From Prof. Goodrich's book it is clear that he takes the view that the mental activities were unconscious during all the earlier stages of evolution and that this " property " only appeared quite late in the process. On p. 186 he writes: " Lastly, we are still in the dark as regards the evolution of consciousness, the highest stage in the development of the mental processes, for our knowledge of the anatomical structure and physico-chemical processes which accompany it is still too incomplete to enable us to determine when it first made its appearance in the animal series." Might we not go a step further and say we shall *never* be able to tell when consciousness first made its appearance, from a knowledge of the *physico-chemical* processes which accompany it? For how do we know that any other organism is conscious but ourselves? We infer without hesitation that other men are conscious; developed speech compels us to make this inference with the utmost conviction; but how do we know that a dog is conscious when it howls from a kick? The physiological panpsychist would be well within his ground in saying that the howl was merely a physical process accompanied certainly by mental activity, but he could make no pronouncement about consciousness. Natural science cannot decide this question. For it is inconceivable that from a study of the living brain we should be able to point (even metaphorically) to a particular change that may be occurring and say: This is accompanied by consciousness. It certainly could not be settled from the study of a dog's brain, nor from a dead human brain, not even from a living brain (animal or human) *under an anæsthetic!*

At this point recourse is had to another device to account for the mental processes becoming conscious. This is the Principle of Emergence. It derives its inception from the fact that when two substances combine chemically the compound has different properties from either of the constituents, properties which could not be predicted from those of either of the latter. This fact is extended to the gradual elaboration of the organic compounds and the consequent emergence of more and more complex properties. This, of course, is not an explanatory principle, but merely a descriptive one. When applied to the mental series it is supposed that, as they increased in complexity, new properties similarly emerged in them, culminating finally in the appearance of consciousness; but this concept does not help us very much in the mental sphere even for descriptive purposes, for we know, and can know, nothing about the mental processes during their supposed long unconscious periods.

Immediately following the passage last quoted Prof. Goodrich continues: "We can tell approximately at what stage in the ontogeny of individuals of our own species consciousness begins to manifest itself as the tissues become differentiated, but as to its phylogenetic origin, we can only say that it probably appeared, as we know it in ourselves, when the cerebral hemispheres reached the high state of development seen in man, though the lower animals may possess it in some simpler stage of development." The difficulties of inferring the condition of mental development from a study of the *differentiation of the tissues* are vividly brought before us in a recent paper by I. D. Suttie[1] criticising the statements of J. M. Baldwin regarding the parallel between mental and cerebral evolution. Referring to passages in the *Mental Development of the Child and the Race* of the latter author, Suttie points out that Baldwin regards "human development as beginning at the very beginning—on a psychological level with the protista," and that he is arguing that "the evolutionary parallel to the stage of mental development of the human being at birth is to be found among the invertebrates, and so on for the later phases." Farther on Suttie writes: "If, however, we endeavour to fill in the gaps in our knowledge of mental development in the infant by a study of the physical correlate of mind, we must credit him with a mentality not substantially inferior to that of an adult man. In complexity, the brain already exceeds that of the adult of any non-human species. If, on the other hand, we were to make inferences about his brain from an observation of his behaviour we might well conclude that it is simpler, more primitive than the central nervous system of many invertebrates. Yet if the principle of psycho-physical parallelism were a trustworthy guide . . . we should reach identical results from either side."

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[1] *Journal of Neurology and Psychopathology*, vol. v, No. 17, p. 9.

This introduces us to another aspect of the doctrine of parallelism when applied to evolution, namely, the corollary that recapitulation in the physical sphere is necessarily accompanied by exactly parallel recapitulation in the psychical series. It is against this doctrine, and its consequences for psychological medicine, so widely held by modern writers, such as Sir Archdall Reid, that Dr. Suttie's criticisms are directed. He calls attention, in the first place; to the fact that the doctrine of recapitulation, in the extreme form propounded by Haeckel, is no longer supported by modern biologists. Prof. Goodrich himself states this very clearly on p. 146 of his book, but the fact does not appear to be familiar to modern psychologists. If this premise is denied it, then mental recapitulation falls to the ground and Suttie also points out many other difficulties which follow the application of this doctrine especially in the cultural and affective spheres. For further details the reader may be referred to the original paper.

If we have dwelt so much on the last section of Prof. Goodrich's book it is because, apart from the intrinsic interest of the subject, it has such important consequences in human affairs. Starting from the empirical data of natural science, our speculations reach to conceptions which extend far beyond them, and which admit of deductions being made that have their reverberations in every sphere of human endeavour. How important it is to distinguish between scientific hypothesis and metaphysical speculation, between the province of natural science and that of psychology, we have already pointed out, but an examination of current physiological writings suffices to show how frequently this precaution is neglected. Anyone interested in medical education cannot but regret the exclusively physiological approach to mental processes which at present obtains in the medical curriculum, with its unfortunate consequences for the diagnosis and treatment of mental disease. Professor Goodrich himself, in effect, emphatically repudiates this attitude when he writes (p. 176): "The physiologist is, however, daily extending our knowledge of the metabolic processes, and as far as he advances he discards the psychical 'explanation.' But in doing so he often ignores the passage from one abstraction to the other, and erroneously concludes that the mental processes are insignificant, superfluous, or non-existent. He imagines that he has reduced them to mere physics and chemistry—an error into which we must not fall. If the whole chain of physico-chemical metabolic processes going on even in the human body and brain be some day discovered, the mental processes will still remain untouched and incapable of being described in the same terms." It might furthermore be added that the very terms "physico-chemical" and "metabolic" are used for the expression of future hopes rather than for the description of present knowledge. For the concepts used in modern neurology, even in describing the most simple *nervous* processes, are "neurone," "impulse," "inhibition," etc., not physico-chemical terms at all, and when the neurologist attempts to penetrate the deeper recesses of the brain his terminology tends to become correspondingly more misty.

When we compare the present position, as represented by this book,[1] with that adopted by the Victorian evolutionists, we cannot but regard the step from epiphenomenalism, and its metaphysical basis of materialism, to parallelism, and the metaphysical doctrines of Spinoza, as one of advance, even though some may regret that it has not yet reached so far as interactionism. But interactionism has implications for biology which few modern biologists are willing to admit. Parallelism has the great advantage that it permits the development of a purely mechanistic biology, with its great heuristic merits, without doing violence to psychology.

Of the purely biological part of Prof. Goodrich's book it would perhaps be superfluous to write. His contributions to morphology are too well known to need any introduction to readers of SCIENCE PROGRESS. If any feature were singled out for special mention it would be the particularly lucid way in which the author criticises the confusion which exists in the use of such terms as "variation," "acquired characters," and others used in genetics. Prof. Goodrich concludes the section "Darwinism and Heredity" with the words: "No case of the supposed transmission of modifications has yet been brought forward which could not be better explained in other ways." Prof. E. W. MacBride, on the other hand, in a somewhat similar book for the general reader,[2] states that Kammerer's experiments (to which Prof. Goodrich does not refer) "demonstrate Lamarck's principle in the clearest way." Should *both* books come into his hands the general reader will perhaps be puzzled at this extreme divergence of opinion, but he will at least be stimulated to think. If, on the other hand, he only reads one authority he may carry away the impression that the fundamental problems of biology have been solved, and only the details remain to be worked out !

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[1] The same point of view appears to be taken in the biochemical article of the recent *General Cytology* edited by E. V. Cowdry.

[2] *An Introduction to the Study of Heredity.* London, 1924.

THE PHYSICS OF EVOLUTION.—By β_3. Being a review of **The Elements of Physical Biology.** By ALFRED J. LOTKA, M.A., D.Sc. (pp. xxx + 460). (Baltimore: Williams & Wilkins Co., 1925; London: Baillière, Tindall & Cox. Price 25*s.* net.)

PERHAPS one of the most satisfactory views of the nature of Science is that which regards its function as being the description of the phenomena of perception by means of conceptual schemes which are regarded as being the more satisfactory as they are the more comprehensive. And it is this view possibly which has led Dr. Lotka to give us his interesting and ambitious mechanical theory of evolution.

Starting from the definition that evolution is the history of a system undergoing "irreversible" changes, the subject is developed very largely by means of analogies with physical chemistry and thermodynamics, the latter of which, in the law of increasing entropy of an isolated system, provides a typical example of an irreversible change. Another analogy between these branches of physical science and the biological sciences is found in the readiness with which the statistical method is applicable to both.

After an introduction in which this point of view is developed, the work is divided into three main portions dealing respectively with the "kinetics," the "statics," and the "energetics" of life-bearing systems.

Kinetics is here conceived as a description of the changes in the mass relations of living organisms without regard to the associated energy changes. Much use is made of a system of equations of the type $\frac{dX_i}{dt} = F_i(X_1, X_2 \ldots X, P, Q \ldots)$ which express the rates of growth of each of a set of different species in terms of its own numbers (or mass X_i) and the numbers of certain other species (X_1, X_2, etc.), together with certain parameters (P, Q . . .) such as climate temperature and so forth, on which the growth is conceived to depend. A system of equations of this type is apparently chosen owing to the analogy with "completely damped" systems in dynamics—systems which are necessarily undergoing "irreversible" changes. The question of the stability of the equilibrium position of such a system is also discussed. The Verhulst-Pearl curve for the growth of populations is deduced as a particular case, and some numerical data, to which the curve is fitted, are given for both human and other populations. The Ross equations for the growth of malaria in mosquito and human populations and the relations between them are also discussed, and there are some further illustrations from parasitology, while room is also found here for some treatment of survival curves.

In the next section on " Statics," stability and non-stability of equilibrium are considered at greater length, and there the discussion is again illustrated by the Ross malaria equations. The question of inter-species equilibrium or the equilibrium which will arise between species preying or otherwise mutually dependent on one another next receives attention ; and this is followed by a long description of " the stage of the life drama " in which details are given of the circulation of water, nitrogen, phosphorus, and other elements through the organic and inorganic world. This is very suggestive but somewhat speculative, and, though we are given many numerical estimates, our confidence in these figures is not enhanced when we find two estimates for the proportion of the total water annually in circulation, which takes actual part in the organic circulation, as divergent from one another as one-sixth from one-seven-hundredth. The section on " Statics " concludes with a discussion of " parameters of state " quantities, such as area available, rent, climate, population density, and the like, which may be conceived to influence the growth of organisms.

The final section, on " Energetics," develops the conception of living organisms and, in particular, human beings as the " energy transformers " of nature. " The picture we must keep before us, then, is that of a great world engine or energy transformer composed of a multitude of subsidiary units, each separately and all together as a whole, working in a cycle." The nature of the subsidiary units is then considered in some detail : they have " receptors " such as eyes and ears, " elaborators " such as memory and reason, " adjustors " or stimuli to responsive action, and " effectors " such as wings, feet, or hands. In the human species these are supplemented by a number of artificial aids similarly classified. The development of this theme leads the author into physiology and psychology, and the book closes with a chapter on consciousness.

An essential of any conceptual scheme that is to have scientific value is its verifiability by the facts of experience ; in this respect Darwin's work was a model. The results of more than twenty years' careful observation and thought were presented to the world, all unified by the conception of natural selection in a theory which was perhaps as amply verified by observation as any non-quantitative theory can be.

If an author chooses to present a theory in a mathematical form, this must stand or fall by appeal to numerical data, and if this is lacking the theory must be regarded as purely speculative. Now, Dr. Lotka's theory of evolution seems, as far as it is verified at all by observation, to depend on the fact that certain collections of statistical data can be fitted by curves whose differential equations are of the same form as certain equations which describe irreversible changes in physics. But there is a danger in interpreting a curve fitted to statistical data as providing anything in the nature of a biological law, because statistical data can often be fitted equally well by curves whose analytical forms differ much from one another and are obtained on very different *a priori* assumptions. Brownlee[1] has given instances of this in epidemiology, nor, in his examples, do those forms based on assumptions which might seem *a priori* most likely, always give the best fits. Again, Pearl's data for the population of the United States might, it seems to us, have been equally well fitted with an ordinary cubic curve, a form not obviously derivable from Dr. Lotka's fundamental equations.

Though the author's general theory appears to be somewhat ultra-speculative, no careful reader of the book would have anything but admiration for the great mass of knowledge about quantitative biological relations which he has succeeded in compressing within the limits of one volume. The style (apart from the mathematics) is likely to appeal to the general reader, plentiful use is made of analogy, which, as long as it is remembered as being such, is full of suggestiveness. For example: " The drama of life is like a puppet show in which stage, scenery, actors and all are made of the same stuff. The players indeed have 'their exits and their entrances,' but the exit is by way of translation into the substance of the stage; and each entrance is a transformation scene. So stage and players are bound together in the close partnership of an intimate comedy; and if we would catch the spirit of the piece, our attention must not all be absorbed in the characters alone, but must be extended also to the scene of which they are born, on which they play their part, and with which in a little while they merge again."

On the last page of this book appears the motto " Mon livre, c'est moi." When the reader reflects on the fact that in this one volume physics, chemistry, geology, epidemiology and vital statistics, parasitology, physiology and psychology, all find a place, he will perhaps feel that the author might have added the bold words of Francis Bacon, " I take all knowledge to be my province."

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[1] *Proceedings of the Royal Society of Medicine*, vol. ii, On Epidemiology, p. 126.

REVIEWS

MATHEMATICS

History of Mathematics. Volume I. General survey of the History of Elementary Mathematics, 1923. [Pp. xxii + 596.] Volume II. Special Topics of Elementary Mathematics, 1925. [Pp. xii + 725.] By DAVID EUGENE SMITH. (London: Ginn & Company. Price 21*s*. each volume.)

THE sub-titles of the two volumes of this significant and unique addition to the literature on the history of mathematics exhibit clearly that this work is chiefly concerned with the history of *elementary* mathematics, but the general title unfortunately does not give any evidence of this important feature. The term "elementary" applies more clearly to the present work than to the work, involving about the same number of pages, recently published by J. Tropfke under the title *Geschichte der Elementar-Mathematik*, which the author of the work under review actually calls " the best history of elementary mathematics," volume i, page xv. The sub-title of the second volume suggests the important fact that the present work does not aim to cover the entire field of the history of elementary mathematics. It is especially weak as regards recent developments in this field, and hence it is not surprising that the name of such a prominent worker as F. Klein does not appear in the indexes of these volumes. His name is, however, incidentally mentioned in volume ii.

In volume i the table of contents is followed by a brief bibliography and six pages headed " Pronunciation, transliteration, and spelling of proper names." On the closing page of the bibliography one finds references to various extensive works on biography, including several which were completed sixty years ago. The latter are recommended without a word of warning as regards the care which should be exercised in the use of such old works. There has been great progress in the history of mathematics during the last sixty years, and it is very important that those who are beginning the study of this subject should be aware of the need of caution in the use of literature, since the exercise of such caution is one of the most useful and most lasting benefits that may be derived from a first course in the history of our subject. Recently G. Loria directed attention to the need of such caution even in the study of the more recent biographies of mathematicians (*Scientia*, volume xxxv, 1924, page 10). It may be interesting to note here that, while the *De vita propria*, by H. Cardan, is explicitly a basis of the biographical sketch of this eminent mathematician in the eleventh edition of the *Encyclopædia Britannica*, G. Loria points out in said article that it is of little value as an historical document.

The main object of the present work is to supply " teachers and students with a usable textbook on the history of elementary mathematics, that is, of mathematics through the first steps in the calculus. . . . The effort has also been made to introduce enough of the anecdote to relieve the monotony of mere historical statement and to reveal the mathematician as a human being like others of his race." Teachers who will use the work as a textbook will probably find that the topics for discussion which are suggested at the close of each of the twenty chapters constitute a very useful feature. The work can be used profitably by those who know very little mathematics. Even those who are interested only in elementary arithmetic and its teaching find here a large amount of inspiring information relating to their work. The university student of mathematics would probably, as a rule, prefer a course in the history of his subject in which the development of the mathematical concepts and the more modern advances relating to elementary mathematics receive greater emphasis.

The first edition of such an extensive work on the history of elementary mathematics may reasonably be expected to involve a considerable number of inaccuracies. It is not the purpose of the present review to furnish a list thereof, especially since a list of suggested modifications relating to volume i appeared in *School Science and Mathematics*, volume 24 (1924), page 939, and a similar list relating to volume ii is expected to appear in a later issue of the same journal. Sometimes contradictions appear more serious than they really are. For instance, on page 301 of volume i of the work under review it is stated that a *second edition* of Bombelli's noted work on algebra appeared at Bologna in 1579. This statement is flatly contradicted by G. Eneström in " Tribune publique " 4 of the *Encyclopédie des Sciences Mathématiques*, as well as by G. Vivanti in *Periodica di Matematiche*, volume v (1925), page 39. Notwithstanding the fact that we have here an obvious contradiction, it should not be assumed that the careful reader of the present work will fail to learn the essential facts, since it is merely a question of what constitutes a second edition, and there naturally are differences of views as regards this point.

The reviewer feels compelled to note here a few details relating to a feature of the present work which impressed him unfavourably and appears to him as fundamental. This feature is clearly exhibited by the first two pages of the tenth chapter of volume i. The opening sentence of this chapter is as follows: " Since this work is concerned primarily with the history of elementary mathematics, it would be quite justifiable to set its limit at the close of the 17th century." It may perhaps be assumed that most readers will not take this statement seriously, since our author fortunately did not go quite to the extreme of setting the upper limit of his work at the close of the 17th century. There are, however, a number of other statements on these two pages which support the one quoted above and are apt to be taken more seriously by the beginner in the history of mathematics. For instance, in the second paragraph of this chapter we are told that the textbook on algebra that is used in the secondary schools and in the freshman course in the college " contains no mathematics that was not generally known " before 1700.

At the University of Illinois, for instance, we certainly teach many things in our freshman course in algebra which were not only *not generally known*, but which were not known at all before 1700, and we think they are mathematics. For instance, we teach theorems about determinants that were entirely unknown at that time. The same is true as regards complex numbers. Sometimes we teach partial fractions and Cauchy's tests relating to the convergency of infinite series in this course. Both of these subjects were entirely unknown in 1700. According to Tropfke's *Geschichte der Elementar-Mathematik*, volume ii (1921), page 78, the eighteenth century suffered because a satisfactory introduction of negative numbers was then still lacking. Hence it seems very far from the truth to imply that our freshman courses in algebra contain no mathematics that was not generally known before 1700.

Those teachers who recall the very fundamental place which Taylor's theorem occupies in a modern course in elementary calculus and the use made therein of partial fractions in integration will probably desire to direct the attention of their students who may be using the present work as a textbook to desirable modifications relating to the following sentence: " The calculus has been greatly improved with respect to its foundation principles and the method of presentation, but the elementary calculus that is taught in our colleges, both differential and integral, with its most important applications, was familiar by the year 1700." On the top of the same page we find the striking statement that "Euclidean geometry is what it was then." Partly on account of such statements the reviewer was forced to conclude that the present work would not attract the advanced student who desires mainly to broaden and deepen his mathematical insight by the study of the history of our subject. This conclusion is also supported by the following statement: "Fibonacci (1202) gave $\frac{1}{2}.2^2\ (2^2-1)=6$, $\frac{1}{2}.2^3\ (2^3-1)=28$, $\frac{1}{2}.2^5\ (2^5-1)=496$ as perfect numbers, and so in general for $\frac{1}{2}.2^p\ (2^p-1)$ where 2^p-1 is prime,—a rule which holds for the first eight perfect numbers but is not universal" (volume ii, page 21).

Among the many other statements which made a very unfavourable impression on the reviewer is the following, relating to Heron: "He was able to solve the equation which we write in the form $ax^2+bx+c=0$, so that the general quadratic as we know it to-day was thus fully mastered by the Greek mathematicians" (volume i, page 126). On page 444 of volume ii we are told that "the Greeks were able to solve the quadratic equation by geometric methods." The former of these two statements involves a fundamentally incorrect conception as regards the algebraic attainments of the ancient Greeks in view of their limited number system. The latter is less objectionable, and is found in many other places; but it is obviously inaccurate, since the Greeks knew nothing about the geometric representation of ordinary complex numbers and did not consider negative roots. In fact, if we understand by geometric solution the construction of points, or line segments, representing the numbers which are the roots of a given quadratic equation, as is commonly done by the modern student of elementary mathematics, the ancient Greeks were far from solving the general quadratic equation geometrically even for the case when the roots are real.

In general, mathematical questions receive very little attention in the present work, but one finds here an unusual richness as regards historical data relating to certain topics of elementary mathematics. A characteristic feature is the emphasis on the mathematics of China and Japan, and on mathematical archæology, notwithstanding the fact that China and Japan seem to have contributed little towards the development of mathematics. The large number of reproductions, sometimes representing purely fanciful original pictures, will doubtless attract some readers who have not heretofore become interested in histories of our subject. Hence it may be hoped that this work will render real mathematical service by widening the circle of those who take some interest in the development of an intellectual heritage which all respect but few appropriate liberally. In America we now have two comparatively recent works which bear the general title *History of Mathematics*. Fortunately they supplement each other in part as regards the fields which they aim to cover. They also contradict each other in various places, and each of them involves a large number of other questionable statements. It is hoped that references to such statements will tend to increase the number of those readers who will extend their historical studies beyond the limits of these works.

G. A. MILLER.

Notations et Formules Vectorielles. Par A. LAFAY. [Pp. 36.] (Paris: Gauthier-Villars & Cie., 1925. Price 6 frs.)

THE author has collected together into a little pamphlet the elementary formulæ of vector analysis, leading up to the theorems of Green and Stokes. Unfortunately, there seems even yet to be no uniformity in terminology or notation. M. Lafay objects to "gradient" and "divergence" and "curl" (or "rot") on the ground that they arise from the interpretation of formulæ of hydrodynamics, and that except in this special case they have no more *raison d'être* than the word "fluxion" used by Newton for the derivative of a function. But one cannot help feeling that they have come to stay. As regards notation, M. Lafay follows M. H. Resal, though he gives in a footnote (p. 6), as is right and proper, the notations used by other authors. He has a fondness for multiplying bars over letters, which is horrid for the printers, but at the same time he objects to the common practice of denoting a vector by Clarendon type, which is hard to represent in manuscript or on the blackboard. This is a useful little book.

F. P. W.

Elements of the Mathematical Theory of Limits. By J. G. LEATHEM, Sc.D. [Pp. viii + 288.] (London: G. Bell & Sons, Ltd., 1925. Price 14*s*. net.)

AT the time of Dr. Leathem's death in March 1923, the manuscript of this book was substantially complete—even as to the Preface. It has been seen through the press by Prof. H. F. Baker and Prof. E. T. Whittaker, who have followed Dr. Leathem's text without alteration except in correcting obvious slips of the pen and making slight changes to remove obscurities. The result is an interesting and well-written volume which will be of great value to the young man who is perhaps not quite in a sufficiently advanced stage to be able to appreciate Hardy's *Pure Mathematics*. The treatment is elementary and clear; difficulties are not shirked, but are definitely indicated, their fuller discussion being left until a later stage. The author is careful to point out that what may be called the "pathological" study of functions may be postponed and that, for all but special exceptional values of the independent variable, the functions commonly employed in elementary mathematics are continuous. "The practical policy is generally to assume continuity, but to keep a look out for discontinuities and the special values of the variable to which they correspond" (p. 52).

The first part is introductory, containing illustrations both arithmetical and geometrical of tendency to a limit, and giving useful warnings against loose statements about "infinity." The author is rightly insistent upon the necessity of being able to analyse, in a grammatical sense, a statement expressed in symbols, and he suggests (p. 33) "that in elementary mathematics we may use the symbol ∞, but never as a noun."

Part II gives the general theory and includes chapters on infinitesimals and their orders, on asymptotic approximation, on differential coefficients (though the notation of the differential calculus is not introduced), and on the exponential and logarithmic limits.

Finally, Part III applies the general theory to infinite series and products, but stops short of double series and uniform convergence, it being thought better to keep clear of double limits in a first study of the subject. There are numerous examples throughout the book.

Chap. 22 (Existence Theorems, etc.) and the last chapter of the book (Irrational Numbers) are perhaps the least satisfactory and one may be inclined to doubt whether they should not have been placed earlier. However, they contain much sound advice and instruction.

Most people are aware that the introduction of the "arrow" notation, now almost universal, for tendency to limit is due to Dr. Leathem; it was first given in the tract on *Surface and Volume Integrals* (Cambridge, 1905). But with regard to asymptotic approximation the author is perhaps less happy; the symbol $(-)$ is suggested, but the symbol $\backsim$ which Dr. Leathem objects to as being used already in England to express a difference seems to have firmly established itself, and men who have attended Mr. Littlewood's lectures in Cambridge, at any rate, have by now learned to say that "x twiddles y" without a blush.

F. P. W.

Conformal Representation. By Leo Lewent. Translated by R. Jones and D. H. Williams. [Pp. viii + 146.] (London: Methuen & Co., Ltd., 1925. Price 7*s.* 6*d.* net.)

This book is intended for applied mathematicians who require to make use of the method of conformal representation. Results in the theory of functions are accordingly explained where necessary, and after simple illustrative examples (and some remarks on Riemann Surfaces which engineers may boggle at, but which it will do them good to read) the author wisely states without proof Riemann's general theorem on the possibility of representing any simply-connected area conformally upon the interior of the unit circle, saying explicitly that the applications of the method depend upon its truth. The last chapter, added by W. Blaschke after Dr. Lewent's death, deals, on the assumption of the Riemann theorem, with the well-known Schwarz-Christoffel transformation for a convex polygon, and Dr. Blaschke naturally cannot resist the temptation to talk a little about automorphic functions. This chapter, and indeed the whole book, is well worth reading even by the pure mathematician, though he may consider the working out of some of the examples in the earlier part unnecessarily complicated.

What of the translation? Well, give me the German original every time! It is so much easier to understand. Here and there are sentences which are completely unintelligible in the English version, but which are quite straightforward in the German, though perhaps hard to translate. Examples are the two paragraphs on the proof of Riemann's theorem (pp. 100–1)—the sentence on the work of Schwarz being turned into nonsense—the concluding sentence of the statement of the theorem (p. 96), which does not contain the whole truth, the omission of a word corresponding to "möglicherweise" in the sixth line from the bottom on p. 142, and the translation of "die sich auch auf einzelne Punkte reducieren können" by "and these may be reduced to points" (p. 146). Moreover, the definition of a simply-connected area (p. 97) is not correct in the English version, "unique" is not always an adequate rendering of "eindeutig," and "seine sehr allgemein gehaltenen Darlegungen" does not mean "his exposition, which was considered to be general" (p. 28). Also, why talk about "smooth" surfaces for "schlichte Bereiche" on the last page? Surely "simple regions" is far better. And "Fricke's lectures on Klein's work on elliptic functions" is rather a queer way of describing Fricke's edition of Klein's lectures on the elliptic modular functions.

As a counterblast we may note that, however surprised the reader may be to be told (p. 139) that the equation

$$y^2 = (x - x_1)\ (x - x_2)\ (x - x_3)\ (x - x_4)$$

represents a plane cubic curve with no double point, this is a slip of Dr. Blaschke's and is not due to the translators. F. P. W.

An Introduction to Mathematical Probability. By Julian Lowell Coolidge. [Pp. xii + 216.] (Oxford: at the Clarendon Press, 1925. Price 15*s.* net.)

The beginning of this book is very unsatisfactory. The author attempts to maintain Venn's definition in terms of frequency, assuming as a first empirical assumption the existence of the limit of a series. As has been shown by Wrinch and Jeffreys (*Phil. Mag.* **38** (1919), 715–31) in an important paper, with which Prof. Coolidge does not seem to be acquainted, the method offers no advantage over that of regarding probability as an entity known to exist independently of definition, intelligible without definition, and perhaps indefinable.

Apart from this the book is a useful compilation. It is inevitable that it should begin with problems about games of chance and balls in urns. As the author says (p. 26): "This branch of the theory of probability has always had a peculiar fascination for a certain type of reader, and was, moreover, the historic basis of the whole science. . . . At the present time the calculus of probabilities is principally occupied with more serious matters." And it is in these more serious matters, the theory of errors, the combination of observations, statistics, that the value of the book lies. There is a good section on least squares, another on curve fitting, a chapter on life insurance, and, a valuable but unusual feature, a chapter on the Kinetic Theory of Gases with a proof of Maxwell's law. At the end are tables to five places of decimals of the exponential and error functions.

One has learned to expect racy expressions and amusing illustrations in a book by Prof. Coolidge, and one is not disappointed. "If all of the inhabitants of Chicago should meet together in one place and get extremely drunk, and then try to go home by guess-work, the chances that at least one would get back to his own bed are almost two out of three. This is one of the cases where it is fortunate that the probability can be calculated beforehand, and we are not forced to seek it experimentally." And so, with quotations from the Magnificat and from *Captains Courageous*, we get to the end. It is surprising that Prof. Coolidge has not drawn upon that mine of good things, Todhunter's *History of Probability*. F. P. W.

Lectures on Cauchy's Problem in Linear Partial Differential Equations. By JACQUES HADAMARD. Silliman Memorial Lectures. [P. x + 316.] (Newhaven: Yale University Press; London: Humphrey Milford, 1923. Price 15*s*. net.)

CAUCHY'S Problem, which is the subject of this book, consists in finding the solution u of a linear partial differential equation of the second order in m independent variables, $x_1, x_2, \ldots x_m$, such that at each point of a given variety S, whose equation is $G(x_1, \ldots x_m) = 0$, u and the derivative of u in some direction given arbitrarily at each point of S, but not tangent to it, shall take given numerical values.

The case of the equation

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} - \frac{1}{c^2}\frac{\partial^2 u}{\partial t^2} = 0$$

of spherical sound-waves, in which we are given u $(= u_0)$ and $\frac{\partial u}{\partial t}$ $(= u_1)$ for $t = 0$, was dealt with by Poisson, who in 1819 found the solution in the form

$$u(x_0, y_0, z_0, t) = \frac{\partial}{\partial t}\{t\mathrm{M}_{ct}(u_0)\} + t\mathrm{M}_{ct}(u_1),$$

where $\mathrm{M}_r(\phi)$ denotes the average value of any function ϕ (x, y, z) on the surface of a sphere of radius r and centre (x_0, y_0, z_0). For cylindrical waves, in which u is independent of z, the result can be immediately deduced from Poisson's by supposing u_0 and u_1 to be independent of z—an example of what Hadamard calls the "method of descent," though "creating a phrase for an idea which is merely childish and has been used since the very first steps of the theory is, I must confess, rather ambitious. It consists in noticing that he who can do more can do less" (p. 49)—but the result shows a remarkable difference from that in the three-dimensional case. It can be expressed in the form

$$u(x_0, y_0, t) = (2\pi c)^{-1}\left[\frac{\partial}{\partial t}\mu_{ct}(u_0) + \mu_{ct}(u_1)\right]$$

where

$$\mu_r(\phi) = \iint \frac{\phi\,dx\,dy}{\sqrt{r^2 - (x - x_0)^2 - (y - y_0)^2}},$$

taken over the area of the circle centre (x_0, y_0) and radius r.

For spherical waves it is at once clear from the formula that if u_0 and u_1 are zero everywhere except within a small region surrounding a definite point P (*i.e.* if the initial impulse is localised in the immediate neighbourhood of P), then the values of u, which represents the effect of that impulse at a later time t, will be zero everywhere except in the immediate neighbourhood of the surface of the sphere with centre P and radius ct. This proposition is sometimes referred to as the mathematical expression of Huygens' principle, but Hadamard prefers to call it "Huygens' minor premise." The remarkable thing is that it is by no means true for cylindrical waves; the integral is here taken all over the *inside* of the circle, the action of an initial impulse at P will be propagated with constant velocity c, as in the former case, and will begin to be perceptible at (x_0, y_0) when the wave thus generated just reaches that point, but *it will continue after that instant.* If initially the impulse is localised within a region S of the plane u will be zero if the circle is entirely outside S, will be different from zero if the circle cuts S, but will remain different from zero if the circle includes S. We thus get in this case a *residual integral*, a tail, and we may say that cylindrical waves are *diffuse* (cf. Lamb: *Hydrodynamics*, 3rd ed., p. 500). In fact, Huygens' minor premise turns out to be a quite special property of certain special equations. Hadamard has proved (p. 177) that it cannot hold for *any* linear partial differential equation of the second order with an odd number of independent variables, any such equation having residual integrals. For an even number of independent variables he obtains (p. 236) a necessary and sufficient condition for the vanishing of the residual integral, but, as he is careful to point out, we do not know how equations satisfying it can be found, or even whether there are any except

$$\frac{\partial^2 u}{\partial x_1^2} + \frac{\partial^2 u}{\partial x_2^2} + \ldots + \frac{\partial^2 u}{\partial x_{2m-1}^2} - \frac{1}{c^2}\frac{\partial^2 u}{\partial t^2} = 0$$

and its trivial transformations.

But these are only particular deductions from the general solution of Cauchy's problem as given by Hadamard. How does he set about it? His method is to generalise the procedure of Kirchhoff, Riemann, and Volterra for certain simple types of equation to any (normal) hyperbolic linear equation with m independent variables. He remarks that the three authors named have a common starting-point, and "indeed, we can say that there is only one formula in the whole theory of linear partial differential equations, no matter to which type they belong" (p. 58). For the potential equation this fundamental formula is, of course, Green's theorem. For any equation

$$F(u) \equiv \sum_{ik} A_{ik} \frac{\partial^2 u}{\partial x_i \partial x_k} + \sum_i B_i \frac{\partial u}{\partial x_i} + Cu = 0$$

the fundamental formula is

$$\int [v\,F(u) - u\,G(v)]\,dT = -\int \left(v\frac{\partial u}{\partial \nu} - u\frac{\partial v}{\partial \nu} + Luv\right) dS$$

in which the integral on the left is an m-fold integral taken throughout a portion T of our space, that on the right is an $(m-1)$-fold integral taken over the boundary S of T, $G(v) = 0$ is the "adjoint" differential equation of $F(u) = 0$, $\partial/\partial\nu$ denotes differentiation along a definite direction called by Hadamard the *transversal* to S (previously called the *conormal* by d'Adhemar)

and $$L = \sum_i \varpi_i \left(B_i - \sum_k \frac{\partial A_{ik}}{\partial x_k}\right),$$

ϖ_1, ϖ_2 . . . being the direction cosines of the normal to S.

In this fundamental formula u is the unknown function of the problem and v is an auxiliary arbitrary function, precisely in the choice of which the whole skill of the operator lies. It is chosen to satisfy the adjoint equation $G(v) = 0$—in the ordinary potential theory it is simply the elementary potential $1/r$ (or $\log 1/r$ if $m = 2$) or one of the quantities (Green's functions) obtained from the elementary potential by the addition of certain terms which remain regular for $r = 0$. The essential thing is the singularity for $r = 0$ — which, it must be remembered, is not merely the single real point (x_0, y_0, z_0) but the whole of the isotropic cone with this point as vertex. In the general case it appears from a theorem due to Le Roux and Delassus (1895) that the singular variety must be a characteristic, *i.e.* if its equation be $G(x_1, x_2, \ldots x_m) = 0$, then G must satisfy the first order equation

$$\Sigma A_{ik} \frac{\partial G}{\partial x_i} \frac{\partial G}{\partial x_k} = 0.$$

Hadamard proves this theorem and its converse (Book II, chap. 3), and goes on to construct an elementary solution for which the singular variety has a node at an arbitrary point of our m-dimensional space. If $\Gamma = 0$ is the equation of this singular variety, called the *characteristic conoid*, then for m odd the elementary solution is of the form $U/\Gamma^{\frac{1}{2}(-m2)}$, where U is a holomorphic function taking at the node a value equal to the reciprocal of the square root of the modulus of the discriminant of the quadratic form $\Sigma A_{ik} x_i x_k$ (we exclude parabolic equations, so that this value is finite), and is quite determinate.

For m even the elementary solution is of the form $U/\Gamma^{(\frac{1}{2}m-2)}$—$V \log \Gamma$, V, being another holomorphic function, but here there is a great degree of indetermination in the result.

It thus appears that, contrary to what one would have expected from the results for $m = 3, 4$ in the simple case of sound-waves, it is m odd which is the simple case, and Hadamard deals with this first, preferring to deduce the results for m even by his method of descent.

But our difficulties are only just beginning. Introducing our elementary solution into the fundamental formula we immediately get landed with meaningless integrals, the quantities under the signs of integration becoming infinite in an impermissible manner upon the characteristic conoid. It was for this reason that the auxiliary function v used by Volterra was not our elementary solution but a function obtained therefrom by a simple integration. In the general case this would add greatly to the complexity of the procedure, and so Hadamard avoids this by what he describes as "a rather paradoxical notion." Consider the integral

$$\int_a^b \frac{A(x)}{(b-x)^{\frac{1}{2}}} dx.$$

Direct differentiation with regard to b would appear to be impossible; it would give

$$-\tfrac{1}{2}\int_a^b \frac{A(x)dx}{(b-x)^{3/2}} + \left[\frac{A(x)}{(b-x)^{1/2}}\right]_{x=b},$$

a sum of two terms, the first of which has no meaning as containing an infinity of order 3/2 under the integral sign and the second being meaningless. But the expression

$$\int^x \frac{A(x)}{(b-x)^{3/2}} dx - 2\frac{A(x)}{(b-x)^{1/2}}$$

approaches a perfectly definite limit as x tends to b, and the same is true if the second term be replaced by $B(x)/(b-x)^{\frac{1}{2}}$, where B is any function of x which satisfies Lipschitz's condition and is such that $B(b) = -2A(b)$, the result obtained being independent of the choice of this function B. It is thus not necessary to indicate what special function B we take, and we may denote the limit by the symbol

$$\left|\overline{\int_a^b \frac{A(x)}{(b-x)^{3/2}} dx}\right.$$

and call it "the finite part" of the integral;

No difficulty arises in defining the same symbol for higher orders of infinity, provided that they are fractional; and we may further develop rules of operation of the symbol and extend the notion to multiple integrals. All this is treated at length in Book III, chap. 1, " A New Kind of Improper Integral." The next chapters obtain the final solution for the case of *m* odd and apply it to familiar equations; Book IV deal with the case of *m* even and gives other applications of the method of descent.

There is a tremendous amount more in the book that we have not even touched upon. For instance, in Book I there is a discussion of non-analytic solutions, with some account of the notion of various orders of neighbourhood and continuity which arose in the Calculus of Variations, and Book II contains a good deal of information with regard to differential geometry of many dimensions, and geodesics in particular—in fact the book most frequently referred to in the foot-notes is Darboux's *Théorie des Surfaces.*

But enough has been said to make it clear that this is a book to be read. The subject is a difficult one, but the style is delightful, and the volume will be of interest and of value not only to the specialist but also to any serious student of the mathematics—or, as Hadamard would say, to any geometer—if only for the emphasis laid upon Poincaré's remark: " Il n'y a plus des problèmes résolus et d'autres qui ne le sont pas; il y a seulement des problèmes *plus ou moins résolus.*" F. P. W.

PHYSICS

Atoms and Rays. By SIR OLIVER LODGE, F.R.S. [Pp. ix + 208, with 8 figures and 1 plate.] (London: Ernest Benn, 1924. Price 21*s.* net.)

FOR many centuries the name Science meant something magical, inaccessible to the common mind, knowledge obtainable only by a few. With the present generation, which knows everything about wireless and nothing about electricity, this is no longer true, and there is a great thirst for that type of knowledge once thought to be the privileged possession of an élite. Most scientists are far too engrossed in their subject to satisfy this tendency of popular thought, although it lies far deeper than passing fancy; but Sir Oliver Lodge has always felt that the sharing of scientific knowledge with his fellow-men is a duty imposed by his own dependence on them, and has lavished much of his time and thought on this task. In the present volume he has made a survey of the attempts which are being made to co-ordinate our present knowledge of the fine structure of matter; although he sees clearly the incompleteness of these attempts. But the book is far more than a mere survey, it is a sermon in atoms and golf and tennis; a wealth of marshalled fact adorned by an even greater wealth of our English tongue; it reveals modern scientific thought from the very seeds to the buds and the flowers and the fruit, now a growing living mighty structure, with its great yearning, a desire to reach the infinite.

Much of the book defies appraisement or criticism from a scientific point of view, but this is only to be expected, since it is intended for the post-prandial edification and enjoyment of those who toil and spin, but desire also to think. We hope these readers will appreciate their glorious privilege in being presented to the Ether of Space by Sir Oliver Lodge, who can claim half a century of close acquaintance with the Infinite Medium.

In the age of specialisation few will be able to perceive the connections, to which attention is drawn in the first chapter of the book, between the electron and the biological theory of evolution, between chemistry and theology. We can realise the catholicity of this introductory essay by taking a succession of substantives requiring capitals wherever they occur—Ether, Matter, Oxygen, Calcium, Protoplasm, Reproduction, Evolution, Creator.

Next the wonderful story of the periodic table unfolds itself. The treatment is not chronological, but in all the simplicity revealed in the light of the work of Moseley, Rutherford, and Aston. The chapter dealing with matter and energy will come as a great surprise to newspaper readers, who have been taught to await, in fear and trembling, the explosion of an atom. It is the "implosion" which must be looked to as a possible solution of our fuel problems. We learn also of the Christmas present given to science in 1900 by Max Planck, the quantum portmanteau into which so many of our radiation troubles fit so readily. Then we reach the work on crystals by which the Braggs made the first measurements of the wave-lengths of X-rays. This leads us to Bohr's theory, which would be thought to defy quantitative treatment in an elementary way; but Sir Oliver successfully performs the task by "reconstructing the crime," in discussing the analogies which probably led Bohr to his theory. This part of the book will be useful not only to the general reader but to physic students, since it will save them from being, in this part of the subject at any rate, mere reproducers of equations.

The book's conclusion is on a note of praise and hope; perhaps only because every age has called itself a dawn. Perhaps, as Sir Oliver suggests, some Newton will arise and put our house in order by reducing the number of our postulates. The sceptics are wondering if we shall next reach the planetary electron and the vortex quantum, and if this will be any advance except in plausibility.

Although the book seems unnecessarily expensive, it is a valuable contribution to the gaiety of scientists and to the edification of the general public.

J. H. S.

The Structure of Crystals. By Ralph W. G. Wyckoff. American Chemical Society Monograph Series. [Pp. 462, with 213 figures.] (New York: The Chemical Catalog Co., 1924. Price 6 dollars.)

Although this volume appears in a series devoted to chemistry, it will be readable only to a small class of chemists, those who are already familiar not only with the morphology of crystals but also with the theory of space groups. It is true that Chapter I, on "The Symmetry Characteristics of Crystals," is intended as an introduction to descriptive and mathematical crystallography, but it is far too condensed to be of any use to the beginner.

Chapter II is a very concise and comprehensive account of the properties of X-rays which are relevant to their employment in crystallography. Fig. 54, showing the spectrum obtained from tungsten using calcite as a "reflector," gives more information than would have been thought possible in a single photograph, for it shows the "quantum edge," the critical absorption limits for silver and bromine, and the L series of tungsten. This figure is typical of more than sixty beautiful photographic reproductions contained in the book, indicative of the author's splendid technique as well as his wisdom in selection.

In the account of the interaction of X-rays and crystals, the style of the first chapter again appears, and the calculation of the positions of diffraction maxima is treated far too generally for the reader who takes his cartesians sadly.

The summary on p. 107, which gives the three postulates used in crystal structure determination, should be thoroughly absorbed by all interested in crystallography, because of the great difficulty of separating pure speculation from actual experimental results in many papers written on this subject. The final postulate, that the results of the theory of space groups define all the equilibrium atomic positions possible for any crystal, is shown to be at variance (*cf.* Part II of this book), with the results for the ammonium compounds and for cesium dichloroiodide.

Chapters IV, V, and VI deal with the three methods of determination of the positions of diffraction maxima, viz. the Lane method, the rotating crystal method, and the "powder" method. The graphical processes for interpretation of photographs will be found very useful and time-saving, especially as in ordinary experimental practice we are only concerned with the identification of planes giving a particular maximum rather than with the exact measurement of interfacial angles.

The penultimate chapter of the first part of the book gives the method of determining crystal structure from the X-ray data. Wyckoff has taken a great part in the development of this method, which is now very complete and final in the present state of our knowledge. However, the greatest advances in this field were made by purely intuitive methods, and there has been practically no modification of the earlier results since the creation of the more complete instrument.

The second part of the book gives the results obtained by the X-ray examination of crystals. It is interesting to notice that these purely geometrical methods have met with great success in organic compounds, whilst the results for relatively simple inorganic salts are often inconclusive; this will come as no surprise to the organic chemist. The results obtained by diffraction of X-rays by non-crystalline media are as yet not sufficiently understood to be of value to the chemist.

This book is the most useful yet compiled for workers in this particular branch. It will fulfil admirably the duty of a monograph designed to save months of searching and reading for beginners in some branch of research.

J. H. S.

Intermediate Light. By R. A. HOUSTOUN, M.A., Ph.D., D.Sc. [Pp. x + 228, with coloured frontispiece and 162 text figures.] (London: Longmans, Green & Co., 1925. Price 6*s*. net.)

IN this book Dr. Houstoun gives a very able and interesting presentation of the subject of Light to the Intermediate or First Science Standard of the various universities. The subject-matter is arranged in nine chapters under the headings photometry, reflection, refraction, spherical mirrors, lenses, optical instruments, the spectrometer and the spectrum, the eye and colour vision, and the nature of light. The treatment throughout is thorough and complete, except that possibly one might desire the inclusion and explanation of such terms as the " mean horizontal candle power," for the benefit of those students who will eventually turn their attention to applied science. In particular, the chapter on the eye and colour vision is to be commended for its remarkable clearness and conciseness, and in the last chapter the fundamental experiments on the nature of light and their significance are excellently described. The book is very well illustrated, and the reproductions of continuous, solar, and sodium spectra in the coloured frontispiece should be of great assistance in impressing upon students the essential differences between these several types. Useful examples are given at the end of each chapter, and, in addition, examination questions set by various representative bodies are given at the end of the book. The book is eminently suitable for all classes of intermediate students, and one cannot but wish it every success.

L. F. B.

A Treatise on Electricity. By F. B. PIDDUCK. [Second Edition. Pp. xiv + 664, with 385 illustrations.] (Cambridge: at the University Press, 1925. Price 21*s*. net.)

THIS *Treatise on Electricity* has undoubtedly proved itself such a valuable aid to the more advanced students of physics that the appearance of a second edition is most welcome. The new edition is by no means a mere reprint of the first, for it is evident that a great deal of care has been taken to bring the book thoroughly up to date, and to substitute new and improved figures, wherever possible, for those which appeared in the first edition. In particular, the chapters on electric oscillations and electricity in gases have been rewritten, X-rays are treated in a separate chapter, the section on radioactivity has been enlarged by the inclusion of important work of recent years, and vector analysis has been introduced "to lend conciseness to the theory of the electro-magnetic field." The last chapter is devoted to the electrical theory of matter, and, in addition to sections on the origin of spectra, Bohr's correspondence principle and the Zeeman and Stark effects, one notes, with pleasure, a clear description of the experiments of Gerlach and Stern. The experimental basis of the quantum theory is suitably emphasised. The value of the book would undoubtedly be increased by the inclusion of more references to original papers; it is hoped that this omission may be rectified in a future edition, for the book is likely to remain a standard treatise. L. F. B.

L'Origine Tourbillonnaire de l'Atome et ses consequences. By JEAN VARIN D'AINVELLE. [Pp. 214, with 15 figures.] (Paris: Gauthier Villars, 1924. Price 15 frs.)

ALTHOUGH most people are now quite accustomed to thinking of the atom as resembling a planetary system, it does not seem evident that any new theory of the origin of the stars should lead to a new theory of the evolution of the atom. However, this book by M. Varin d'Ainvelle was inspired by a theory enunciated by M. Belot in his *Essai de Cosmogonie Tourbillonnaire*, on the formation of the stars.

The atoms are supposed to be vortex tubes in the ether, which medium it is necessary to endow with viscosity, compressibility, and susceptibility to temperature changes. This ether is like a cloud enveloping our universe, this cloud itself floating in a sub-ether, a continuous ether possessing fewer of the attributes of matter than the first ether. In this first denser ether neither homogeneity nor repose exists; across its surface there is continual but irregular radiation of heat and energy. These irregularities give rise to ether currents in all directions, and the chance encounter of two currents gives rise to a series of vortices. These vortices vary in size from worlds to atoms, possessing different characteristics according to the nature of the currents and that of the encounters.

There are twenty-four chapters which refer to most of the phenomena of chemistry and physics, and the more recent theories concerning these. The proofs by which these are associated with this new vortex theory are somewhat obscure.

M. Varin d'Ainvelle fully expects that his theory will appear fantastic, owing to what he calls man's unconscious anthropocentricity. He fails to realise that he is constructing a model, which must stand or fall by its power to suggest experimental research. J. H. S.

Isotopes. By F. W. ASTON, Sc.D., F.R.S. Second Edition. [Pp. xi + 182, with 23 figures and 5 plates.] (London: E. Arnold & Co., 1924. Price 10*s*. 6*d*. net.)

PHYSICISTS and chemists are familiar with the great advances which were made in spectroscopy after the improvement of the grating by Rowland, due to the increase in resolving power. Dr. Aston has performed a similar work in perfecting the mass ray spectrograph with results which are now helping us to unravel the intricate mass of spectroscopic data. Not only did Dr. Aston perfect the instrument, but nearly all the experimental data at our disposal in this field are due to his unaided efforts.

A detailed criticism of this work would be almost an impertinence. It is not only a textbook which is indispensable to all students of physics and chemistry, but also an inspiration to them and to all research workers. In these days of number juggling it is refreshing to read an account of solid work which will last. J. H. S.

CHEMISTRY

The Foundations of Colloid Chemistry (a selection of early papers bearing on the subject.) Edited, on behalf of the Colloids Committee of the British Association, by Emil Hatschek. [Pp. 172.] (London: Ernest Benn, Ltd. 1925. Price 18*s.* net.)

This book, which consists of a selection of the early papers of the pioneers of colloid chemistry, serves to show how firmly established were the foundations of this subject in the nineteenth century. It is evident, from the high quality of these reprinted papers, that the work of the preceding centuries can scarcely have been negligible. The records of this knowledge are, however, widely scattered, and no history of the earlier period has yet been written. It is hoped that the Colloids Committee will see their way clear to give us a volume on the work of the preceding centuries.

A large number of the papers reprinted in the present volume are very probably unknown to the majority of chemists. This applies especially to the work of Ascherson, Selmi, Sobrero, and Muthmann. The paper by Ascherson, in which he describes his discovery of the membranes formed between oils and proteins, is written in a manner which belongs to the present day, rather than to the nineteenth century. In this paper is made what is perhaps the first clear statement of the phenomena of adsorption. The papers by Selmi and Sobrero are translated and republished in this volume for the first time. They deal with silver chloride and sulphur sols, and "the pseudo solutions of prussian blue and the influence of salts in destroying them."

The other papers are more accessible. These include work by Faraday on gold sol, Graham on the properties of silicic acid, Muthmann on silver sub-oxide compounds, Bemmelen on the nature of colloids and their water content, and Carey Lea on the allotropic forms of silver.

The volume serves a very useful purpose in making accessible a number of interesting papers which will be valuable for the teacher and student alike.

W. E. G.

A History of Bleaching. By S. H. Higgins, M.Sc. [Pp. viii + 176, with 9 illustrations.] (London: Longmans, Green & Co., 1924. Price 10*s.* 6*d.* net.)

An interesting account of the history of bleaching from the earliest times, in which special emphasis is laid on the influence of chemical inventions on the development of the industry.

The book forms a very valuable contribution to the history of chemical industry, especially with regard to the light it throws on the conditions under which the industry has grown from small beginnings. The story of the bleaching industry is very probably typical of all our older chemical industries. It provides a good illustration of the slow rate of development of a chemical process when large-scale experiments are made by the costly method of trial and error. It also shows clearly the parts played in industry by the chemist and the engineer.

Considerable interest is aroused by the account given of the patent litigation in the industry. The Tennant case provides a very good illustration of the difficulty of protecting chemical processes.

The different periods in the history of bleaching are illustrated by plates which add considerably to the value of the book. W. E. G.

Premier Conseil de Chimie. Institut International de Chimie Solvay. Rapports et Discussions sur Cinq Questions d'Actualitie. [Pp. xvi + 336, with figures.] (Paris: Gauthier-Villars et Cie, 1925. Price 30 fr.)

This volume contains the statutes of the *Institut international de Chimie* founded by M. Ernest Solvay, and a record of the papers read, together with the discussions which followed, at the first meeting of the Institut in 1922. Five problems were discussed at this meeting: (1) Isotopy and Radioactivity, three papers being read by Profs. Soddy, Aston, and Perrin and Urbain respectively; (2) Molecular Structure and X-rays, by Sir W. H. Bragg; (3) Molecular Structure and Optical Activity, to which Sir W. Pope and Prof. Lowry contributed papers; (4) Valency, a paper by M. Mauguin; and (5) Chemical Reactivity, a paper by M. Job being read.

It is to be regretted that the report containing these interesting papers has been delayed so long before publication. The matter which they contain has very largely been published elsewhere since they were read at the Solvay Conference. W. E. G.

A Treatise on Physical Chemistry. A Co-operative Effort by a Group of Physical Chemists. Edited by Hugh S. Taylor, Professor of Physical Chemistry, Princeton University, N.J. [Pp., vol. i, xi + 603 + 41; vol. ii, ix + 621 + 41, with numerous illustrations.] (London: Macmillan & Co., Ltd., 1924. Price 50s. net.)

THIS treatise on physical chemistry is the result of the co-operative effort of a number of physical chemists who have each written one or more chapters on branches of the subject, in which they have special knowledge. On account of the subdivision of labour, it has been possible to make a more adequate survey of modern ideas than would have been possible had the whole book been written by one man.

The book is addressed primarily to advanced and research students in physical chemistry, but the chapters are so graded that the first volume contains the more elementary and the second the more advanced aspects of the subject. The first volume will be very valuable to teachers of physical chemistry, since all branches have been brought up to date by the inclusion of recent theoretical and experimental work. Further, it gives opportunities for comparing the various methods of teaching physical chemistry at present employed in America. The second volume includes more advanced work on electro-chemistry, reaction velocity in homogeneous and heterogenous systems, quantum theory in physical chemistry, the third law of thermodynamics, photo-chemistry, infra-red radiation and chemical reaction, colloid chemistry, and radioactivity. The chapters on these subjects are excellent summaries of these branches of modern physical chemistry. The space allotted to colloid chemistry is, however, rather small. The chapter by Prof. Partington in the first volume on conductance and ionic equilibria is especially valuable for its enormous list of references.

The editor of the book is to be congratulated on the success with which he has co-ordinated the work of his contributors. The wealth of recent experimental material incorporated in the book make it the most important compilation on physical chemistry of the present day.

The book is instructive in that it shows clearly what is now considered to be the scope of physical chemistry. It will very probably help to form the tradition which determines the lines of demarcation between physical chemistry and its sister sciences. The branches of the physical sciences incorporated in this book as branches of physical chemistry, with the exception of the last chapter on radioactivity, all bear on the group of problems concerned with the mechanism, kinetics, and equilibria of chemical reactions. In order to deal adequately with these problems, the physical chemist borrows widely from the physicist. He cannot afford to ignore any physical discoveries which are concerned either directly or indirectly with chemical reactivity. Hence the modern treatise on physical chemistry incorporates accounts of thermodynamical theory, the modern theory of spectra, the quantum theory, etc. As a result of this development, the subject of physical chemistry is much better balanced than was the case twenty years ago, when one of its branches, the theory of dilute solutions, underwent such rapid development. A clearer view of the aims of physical chemistry and its relations with other sciences is now attainable.

The editor of this book gives no clue to the general principles which guided him in the choice of the sub-branches of physical science for his book. In one respect his choice is open to criticism in that he has not given sufficient space to several of those branches of the subject which are of importance to the physiologist. The physiologist is interested not only in the laws of dilute solution and in colloid chemistry, but also in the structure and chemical reactivity of organic compounds, both of which are appropriately studied under physical chemistry. Our knowledge of physico-organic chemistry has not advanced very far, but, in view of its importance for the study of vital phenomena, it would be advantageous if attention were directed to the importance of the problem in treatises in physical chemistry. The subject could readily have been developed under the headings of the relationship between physical properties and chemical constitution of organic compounds, molecular emission and absorption spectra, etc.

The book will be of most value to those students who have already attended an elementary course of physical chemistry, and as a work of reference. W. E. G.

Modern Inorganic Chemistry. By J. W. MELLOR, D.Sc. [Pp. xx + 1103, illustrated. New Edition.] (London: Longmans, Green & Co., 1925. Price 12*s.* 6*d.* net.)

DR. MELLOR is a convinced believer in chemistry as a subject for introducing pupils to scientific methods, as he makes clear in an interesting preface to the new edition of his textbook. Certainly, any student who succeeds in absorbing the contents of this book need fear no examination in inorganic chemistry and, if he has done a corresponding amount of laboratory work, will have had a grounding in the methods of science which will stand him in good stead later on, in whatever calling he may take up.

The general arrangement of the work remains the same as before, but the volume now consists of 1,123 pages as compared with 930 pages of the previous edition, although the price has not been altered.

There are one or two unfortunate errors, such as the repetition of the now inaccurate "displacement rule" on p. 1032, which is no longer held in that form by its proposer or by anyone else; insufficient attention is paid to Moseley's pioneer work on atomic structures and numbers; but apart from such faults as these the book is to be recommended to all teachers and students of inorganic chemistry. F. A. MASON.

The Anthocyanin Pigments of Plants. By Muriel Wheldale Onslow, M.A. Second edition. [Pp. vi + 314.] (Cambridge: The University Press, 1925. Price 21*s.* net.)

THE amount of work which has been expended upon the anthocyanin [illegible]ments, both from the chemical and biological points of view, is so prodigious that it is becoming increasingly difficult to keep abreast of the literature, and it is for this reason that a second edition of this valuable work will be welcomed both by chemists and botanists. The present edition does not differ materially in arrangement or size from the previous one; by a process of condensation some space has been saved, making it possible to devote a further fourteen pages to the bibliography, which now extends to ninety-two pages; the excellent practice of attaching a brief abstract of the contents of each of the papers quoted in the bibliography is one which we should like to see more generally adopted. A perusal of this book cannot fail to impress the reader with the complexity of the problems confronting those who would attempt to unravel biological phenomena; it is one thing to isolate from the plant a complex substance and to establish its constitution by analysis and synthesis, but it is quite a different matter to explain how, and from what, it is formed in the plant, or what its function is; to all these questions a number of diametrically opposed answers can be offered, and, after reviewing all the evidence, one is reluctantly forced to the conclusion that "no definite inference can be drawn"; this, at any rate, is the attitude wisely adopted by the author in her careful and impartial summary of the various aspects of the subject. P. H.

Chemistry to the Time of Dalton. By E. J. Holmyard. Volume III of **Chapters in the History of Science.** [Pp. 125, and illustrations.] (Oxford University Press. Price 2*s*. 6*d*. net.)

One of the results of the modern tendency to humanise the teaching of science is an increased interest in the historical aspect of the study of each branch of the subject. The volume before us is a very readable account of the earlier history of chemistry and its forerunners. It is well that students of science, the experimenters and investigators of the future, should learn the need to combine width of view with the concentration and narrowness of scope imposed upon scientific workers of to-day. No study shows the need to avoid too fixed an idea more than that of the history of chemistry up to the time of Dalton. W. C. B.

The Constituents of Coal Tar. By Percy E. Spielmann, Ph.D., B.Sc., F.I.C. (Monographs on Industrial Chemistry.) (Pp. xii + 219, with two folding charts.] (London, 1924, Longmans, Green & Co. Price 12*s*. 6*d*. net.)

Bituminous Substances. By P. E. Spielmann, Ph.D., B.Sc., F.I.C., with a foreword by J. Kewley. [Pp. xvi + 206, illustrated.] (London, 1925, E. Benn, Ltd. Price 15*s*. net.)

(1) Dr. Spielmann has chosen a very suitable moment to produce his two books, as it is just a century ago that Michael Faraday isolated for the first time his "bicarburet of hydrogen" which we now know as benzene and so initiated the long and triumphant period of progress in research and discovery which has enriched aromatic chemistry during the past 100 years.

It is indeed a far cry from the isolation of benzene in quantity from coal tar by Mansfield to the present day, when nearly a hundred separate components have been isolated from tar, about a dozen of them being common commercial substances.

The book is divided into five parts dealing with coal tar and its formation, the hydrocarbons, oxygen compounds, sulphur compounds, and nitrogen compounds. In addition, details are given for the analysis of "benzoles" and "toluoles" by means of two accompanying charts.

Owing to the large number of substances dealt with and the necessity for compression, the information is at times a little lacking in clarity; thus, under "Diphenyl" is given "Use: for benzidine dyes"; true, the hydrocarbon is the theoretical mother substance of benzidine, but it is certainly never used technically for the preparation of the base; again, phenanthrene is not used in the production of Flavinduline O though the phenanthrene skeleton is probably present in the structure of the dye.

Chemists, however, who have to deal with coal tar products will be grateful to Dr. Spielmann for having summarised the available information on the subject.

(2) Asphalt, or bitumen, is one of the oldest known products derived from crude petroleum, but only in recent years has it developed in importance owing to its value in the construction of roads suitable for motor traffic.

Practice has in this case outrun theory, for, as Dr. Spielmann points out, it is the least understood product of crude petroleum from the chemical point of view, and the author has performed a useful service in bringing together what is known of the chemistry of the bitumens, and has endeavoured to correlate as far as possible their chemical composition with their physical behaviour and properties. A useful section deals also with the actual physical and chemical tests, so that the book should be of real value to those who have to deal with the substances of the asphalt class. F. A. M.

GEOLOGY

The Face of the Earth (Das Antlitz der Erde). Vol. v, Indexes and Maps. By E Suess. Translated by Hertha B. S. Sollas, under the direction of W. J. Sollas. [Pp. 170, with 6 maps.] (Oxford: The Clarendon Press, 1924. Price 15*s*. net.)

This book contains the indexes and certain of the maps appertaining to the English translation of Suess's monumental work, which has been executed by Miss Hertha Sollas under the direction of Prof. W. J. Sollas, and appeared in four volumes about fifteen years ago. The belated appearance of the index is due chiefly to the War. It is not a translation of the original German index, which was found to be very inadequate, but an entirely new compilation from the English translation. The delay had one fortunate result, however, as the late Prof. Suess was enabled to enrich the volume with some new diagrams from his own pen. Eleven pages at the beginning are occupied by an explanation of the three principal maps. In general, the work has been well done. Considering the world-wide scope of Suess's work it is not surprising that some of the geographical names are misspelt, and that the orthography does not conform to any one scheme; we notice, however, that alternative renderings of some names are given. There are one or two bad misprints in the maps. To Prof. Sollas and Miss Sollas are due congratulations and thanks on the completion of their great and useful task.

G. W. T.

Handbook of the Geology of Ireland. By G. A. J. Cole, D.Sc., F.R.S., and T. Hallissy, B.A. [Pp. viii + 82, with 7 illustrations and a map.] (London: T. Murby & Co., 1924. Price 8*s*. 6*d*. net.)

This volume is based on the late Prof. G. A. J. Cole's contributions to that part of the *Handbuch der Regionalen Geologie* which dealt with Great Britain, published in Heidelberg some years ago. The copyright has now been purchased from the German publishers, and a revised edition in two volumes is to be issued, of which we have the first before us. Mr. T. Hallissy, of the Geological Survey of Ireland, was associated with Prof. Cole as joint author.

The book is divided into five sections; the first deals with the morphology, the second, and by far the longest, treats of the stratigraphy and lithology of each formation in turn. Then come sections on general geological history, the orographic elements, and economic geology. Prof. Cole's influence is seen in the retention of the term Gotlandian for Silurian, a usage in which he was practically alone in this country. A statement concerning *Oldhamia radiata* and *antiqua* (p. 9) is rather ambiguously worded, and leaves the reader in doubt as to whether these markings are regarded as organic or inorganic. The boulder bed of the Irish Dalradian, probably on the same horizon as that of the Scottish Highlands, is tentatively assigned a glacial origin, as has also been done recently by Mr. E. M. Anderson, for the Schichallion boulder bed of Perthshire. The lake theory is apparently favoured for the origin of the Old Red Sandstone, although "terrestrial talus" is said to occur (p. 51). The only mistake we have been able to find in this well-printed and well-produced work is in the geological map which serves as a frontispiece, where the Mull of Kintyre is labelled as Arran. This book will remain for a long time as the most comprehensive and yet concise account of the geology of Ireland. G. W. T.

BOTANY

Plant Forms and their Evolution in South Africa. By J. W. Bews, M.A., D.Sc., Professor of Botany in the Natal University College. [Pp. 199, with map and 31 text-illustrations.] (London: Longmans, Green & Co., 1925. Price 12*s.* 6*d.* net.)

This volume treats of the flora of South Africa in such a way as to make it contribute to the general subject of plant geography. It also uses the information available as to the distribution and probable sources of the South African flora to trace the ecological history of the vegetation.

The flora of South Africa is divided into two distinct elements, the tropical-subtropical, and the temperate. The former is regarded as having migrated from the tropics north of this area. There is a dry area in the centre and west of South Africa, which constitutes a barrier, so that the southward invasion is supposed to have been by way of the Eastern side of the Continent. As regards the Temperate flora, it may be stated that there are two views, one which regards it as a relict of an Antarctic flora represented also in Australia and the extreme southern portion of South America, while the other view derives it from the Northern Hemisphere. Professor Bews is of the opinion that this flora is of a mixed nature, having received contributions from both sources. The various systems of classifying plant forms are then discussed, and the author points out that they depend chiefly on the principles enunciated by Drude: (1) "the rôle played by the particular species in vegetation, and (2) its life-history, under conditions prevailing in its habitat, with special reference to duration, protection, and propagation." The evolutionary arrangement of such growth-forms has not yet been attempted, except for the beginning made by Sinnott and Bailey, who hold that the herbaceous forms have been derived from woody types. This view is accepted by Professor Bews, who furthermore expresses the opinion that the primitive tree was sparingly branched and with large undivided leaves, the more important evolutionary tendencies being reduction in size, increase of branching, compound leaves, thorn development, succulence, deciduous leaves and xerophytism, etc. Climbing plants, epiphytes, parasites, herbaceous undergrowth, and aquatics are considered as derivative, and the annual is regarded as one of the most recent types. Evidence for these views is brought forward from the study of the South African flora. It is held that moist tropical forests, stream banks and swamps, the sea-shore, and possibly mountain regions are types of plant habitat which have remained relatively constant from Cretaceous times and it has been found that the more primitive growth forms are more common in these older areas than in the more recent formations. These view-points add to the interest of the description of the types of vegetation met with in South Africa, and the ideas put forward as to the evolution of growth-forms generally constitute a basis for future work on the subject. E. M. C.

Œcology of Plants. By Prof. E. Warming. Second Impression. [Pp. xi+422.] (London: Oxford University Press, 1925. Price 15*s.* net.)

The *Œcology of Plants*, by the late Prof. Warming, based on his *Plantesamfund*, was first published by the Oxford Press in 1909, at a time when the literature of Ecology was even more limited than now. From the outset the work was recognised as an essential part of the equipment of students in this field, a position which it still maintains, despite the great progress in ecology which the last sixteen years have witnessed.

The subject-matter, which is mainly synecological, is too familiar to need enumeration, although the work has for some time been out of print. In rendering this work once more available to the rapidly increasing number of students of ecology, the Oxford Press has laid all botanists under an obligation.

The present impression is an excellent facsimile reproduction of the original, from which it only differs in the slightly thicker paper upon which it is printed. E. J. S.

Plants and Man. By Prof. F. O. Bower, Sc.D., F.R.S. [Pp. xii + 365, with frontispiece and 148 figures.] (London: Macmillan & Co., 1925. Price 14*s*. net.)

This book is based on a series of essays that appeared in *The Glasgow Herald* in 1924, and is a popular exposition of various aspects of the Vegetable Kingdom, more or less related to man's needs and activities.

The description is necessarily general in character, and, if somewhat inconsequent, will attract the general reader from the variety of the subject-matter and the diversity of treatment.

The earlier chapters, which describe the organisation of the plant body, serve as an introduction to the subsequent essays on vegetable foods, timbers, textiles, etc. Various habitats are lightly touched upon, from the comparatively wild moorland to the almost entirely sophisticated vegetation of the flower and kitchen gardens. Other chapters deal with fruits, cereal grains, bacteria, and other subjects less clearly connected with man, such as mycorhiza, fungal parasitism, etc.

There are a few minor inaccuracies, such as the statement on p. 84 that much of the forest clearing in Britain was due to the requirements of shipbuilding, and the implication on p. 74 that the hedgerow elm commonly produces seedlings in this country.

Every author is entitled to his own opinion as to what he should, or should not, include, having regard to the exigencies of space; but we venture to think that the non-technical reader would derive more profit from the perusal of these pages had space been devoted to the explanation of familiar phenomena such as the cause of " warping," the " knots " in timber or the rôle of bacteria in sewage disposal, rather than to descriptions, too brief to be of real value, of the wood used in the construction of a violin or the reproductive processes of flagellates. Whatever opinion we may, however, hold regarding the choice of matter, the manner of presentation is such as should appeal to all readers. E. J. S.

The Romance of the Fungus World. By R. T. Rolfe and F. W. Rolfe. (Pp. xx + 309, with 85 figures.] (London: Chapman & Hall, 1925. Price 12*s*. 6*d*. net.)

The volume before us is a popular account of the fungi, in which the authors have presented, in an interesting manner, both the legendary and real characteristics of the group. The former aspect introduces us to the poetry, actual and metaphorical, of the fairy rings where " twilight fairies tread the circled green," and the references to the group in fiction which perhaps best illustrate the prevailing conception of these organisms.

To the general public the word "fungus" connotes something which is either a delectable dish or a dangerous poison; but those who have expatiated on the latter are under suspicion of having hoped to increase their share of the former. Nowadays, with the growing interest in mycology, a comparatively large number of people are prepared to accept that the mushroom is not alone edible amongst British fungi, and that a large proportion of the toadstools are not poisonous, though it must be admitted that few will be found willing to put their enlightenment to the practical test. The belief, mentioned by Pliny, that the poisonous species can be distinguished from the edible by their colour, still persists even to-day, and is of course as unreliable a test as the effect of the fungus on a silver spoon or the ease with which the skin can be removed from the cap.

Since so little is generally known regarding the gastronomic qualities of most of the group it is scarcely surprising that in other respects myths and superstitions largely occupy the place of any real understanding, and these pages should do much to awaken interest in a rather neglected feature of the country-side and to provide information that will add to the enjoyment of autumn rambles.

The real nature of the fungi is first introduced by a brief account of their structure and characteristics, and a summary of the features of the chief subdivisions, not, we regret to say, entirely free from unexplained technicalities.

The importance of fungi is brought home to the reader in the chapters devoted to the damage which these organisms cause and their uses. Such important crop diseases as the potato blight, the wheat-rust, and the vine disease are responsible for losses amounting annually to many millions of pounds, and it has been estimated that the total annual loss throughout the world due to parasitic fungi alone is between 150 and 300 million pounds. The uses of fungi are varied and numerous, and, in addition to their familiar employment as food, play an indispensable rôle in the production of alcoholic beverages and vinegar. These and minor uses are dealt with, and in the chapter on fungi as food some striking data are furnished, showing that thirty-one species were sold in the market of Munich in 1901, aggregating a total of 1,850,000 lb. The mode of culture of mushrooms on a commercial scale is described, with photographs of the underground beds at Corsham in Wiltshire, where as much as 4–5 cwt. are gathered in a day. Other cultivated species are the Morel and Truffle in France, a species of Jew's-ear in China, and the enormous industry in *Amillaria shiitake* and *A. edodes* in Japan, the crops of which attain an annual value of over one hundred and fifty thousand pounds.

Other chapters describe the more important poisonous species, and some of the curious phenomena connected with fungi, such as their rapidity of growth, luminosity, etc.

The book is well illustrated by a number of excellent photographs from the camera of Mr. A. E. Peck, and should do much towards achieving its expressed object of increasing interest in these plants. E. J. S.

ZOOLOGY

Outlines of General Zoology. By H. H. Newman. [Pp. xvi + 480, with 179 illustrations.] (New York: The Macmillan Company, 1924. Price 16*s.* net.)

In the days of Huxley, when zoological syllabuses first began to take shape, it was natural that systematics should form the backbone of courses in zoology, for in those days comparative anatomy and zoology were practically synonymous. Even so, Huxley himself, in *The Crayfish*, pointed the way to a more general presentation of the subject. More than half a century has passed since then, and many new branches of zoological science have not only arisen, but established important principles, and yet, if we compare the syllabuses of most of our universities to-day with those of fifty years ago, we find these changes very poorly represented. By far the largest part of the student's time is still occupied with the arid details of comparative anatomy and classification, and such topics as experimental embryology, cytology, and animal behaviour, which have such important bearings on the general problems of biology, and are therefore of much greater cultural value, are usually relegated to a small part of the curriculum. Instead of taking its proper place in alignment with the newer developments, comparative anatomy still occupies almost as much time as it formerly did.

Judging from the preface to Professor Newman's *Outlines of General Zoology,* this question has received much more attention in America, and his book represents an attempt to give due weight to all aspects of the subject, based upon over twenty years of teaching experience. The reaction against the old "type method" has, in America, resulted in a tendency to present principles with an insufficient basis of facts, and Professor Newman has endeavoured to arrive at a mean between these two extremes.

This book is divided into four parts. The first introduces the subject as presenting a series of *problems,* instead of following the more usual method of detailing a list of unconnected "-ologies." This is a most admirable feature which characterises the whole book, and presents a great contrast to the dogmatic didactic method of most elementary textbooks. The problem of life in general, and of the unity of the organism, the problems arising out of the discovery and study of cells, and the problems of œcology and classification, are all reviewed in an elementary and general way. Part II deals systematically with a series of the usual invertebrate types, and Part III is devoted to the morphology and physiology of the frog as a type of a vertebrated animal.

Part IV, which occupies about a third of the book, returns again to general principles and discusses in more detail some of the problems of Part I in the light of what has been learnt from the types. The first four chapters of this part are devoted to Modes of Reproduction, the Germ-cell Cycle, Sex and Genetics; the next three deal with Œcology, Adaptation, the "Web of Life," and Geographical Distribution, and the book concludes with three chapters on the Doctrine of Evolution.

Everyone who wishes to see the teaching of zoology freed from dogmatism and the mind of the student liberated from the deadly weight of too much systematics, will welcome this new and original book. Freedom from dogmatism means that the student can not only be taught scientific *facts* but (which is perhaps more important) scientific *method*; putting systematics in its proper perspective in relation to principles means that *memory* will not be allowed to usurp the place of *thought.* J. H. W.

British Birds. By Archibald Thorburn, F.Z.S. Vol. I. [Pp. xii + 176, with 48 plates in colour.] (London: Longmans, Green & Co., 1925. Price 16*s*. net.)

THIS is a new and small edition, in four demy 8vo volumes of the author's earlier work of similar title. The text has been revised and partially rewritten; the illustrations are entirely new. The whole work, when complete, may be purchased for three guineas or each volume separately at 16*s*. net.

The text is slight but very readable, and contains a good deal of general information. The plates are wholly delightful. Except for a few rarities, all the birds of the British list are figured. There is no doubt that the work is the best money's worth that has yet been put on the market of illustrated British bird books. Compared with the earlier edition, the birds are less brilliant, which to our mind is an improvement. The colour renderings of the reproductions are remarkably faithful, although a few of the prints, *e.g.* plates 6 and 29, are slightly "fuzzy." It seems superfluous to comment on the incomparable beauty of the paintings, but, in case their remarkably cheap price should be considered a reflection on the work, let us say that, in spite of the small size and consequent lack of elaboration, we prefer some of the individual plates to anything Mr. Thorburn has yet published. And we can surely pay them no higher tribute.

But we have one serious quarrel with our author in the retention of the nomenclature of Howard Saunders's *Manual of British Birds.* In view of the revision of the text, this is surprising. Since the publication of his first edition, not only has the B.O.U. issued a list of British birds employing all the results of recent work on nomenclature, but Witherby's *Practical Handbook of British Birds* has also appeared. With the exception of a few generic names, the nomenclature herein employed is identical with that of the B.O.U. list. The Handbook, together with Thorburn's present edition, were modern nomenclature used, would have put at the disposal of ornithologists the completest, cheapest and best British bird library of seven volumes that has ever been available. Most of the names used by Saunders have seen their day, and should be honourably buried. It is a matter of regret that they should be deliberately perpetuated in any modern work, but more particularly in the case of one that is assured of as wide a sale as Mr. Thorburn's most certainly is. One could hardly expect an amateur, unfamiliar with the intricacies of nomenclature, to guess that Thorburn's Black-throated Wheatear, *Saxicola occidentalis* (plate 6) is the same thing as Witherby's (or the B.O.U.'s) Eastern Black-eared Wheatear, *Œanthe hispanica hispanica*. The benefits that he might have reaped from uniformity will not be his.

We should like to suggest, if it is in any way feasible, that in the three volumes yet to appear the nomenclature be modernised, and a list of synonyms referring back to volume i be included in volume ii. By purchasing the two works students can then use this beautiful Thorburn directly with the *Practical Handbook*, a combination of the best of everything that cannot be equalled.

W. R.

Birds of America. In three volumes (Nature Lovers' Library), with numerous photographic, black-and-white, and coloured illustrations. Editor-in-Chief, T. Gilbert Pearson. (New York: The University Society Inc., 1923. Price $16.60.)

THESE books are the conjoint work of numerous well-known American ornithologists, under the editorship of Mr. T. Gilbert Pearson, President of the National Association of Audubon Societies. Pagination of the three volumes is not continuous, each having some 270 pages with many illustrations. The majority of black-and-white drawings are by R. I. Brasher, and the colour plates, numbering 106, by Fuertes. The latter, however, were not especially drawn for the present work, having previously appeared in Eaton's *Birds of New York*.

This is essentially a popular bird book, and should serve its purpose admirably. The majority of American birds are considered, most of the omissions being apparently species that do not migrate commonly through the States, *e.g.* white-billed Northern diver, short-billed gull, etc. The more clearly defined sub-species of the States and Southern Canada receive due attention. Since more than a thousand birds are dealt with, treatment is necessarily brief. For each species the best-known popular names are first enumerated, when a general description, a full colour description, an account of the nest and eggs, and, finally, distribution, are given in condensed form. These are followed by short notes on habits, song, economic status and so on in larger type.

The illustrations by Brasher vary considerably in quality, but the majority are good. Fuertes' birds, as always, are remarkable for their character, but his plates lack the finish and technical polish of Brooks or Thorburn. They are well reproduced, and as illustrations for a descriptive work are excellent.

As a general work on American birds for amateur ornithologists we can heartily commend the *Birds of America*.

W. R.

Anatomy and Physiology of the Honey Bee. By R. E. Snodgrass. [Pp. xv + 327, with 108 figures.] (London: McGraw-Hill Publishing Co., 1925. Price 17*s.* 6*d.* net.)

The author of this book has had a wide experience of Bee Culture during his official connection with the Bureau of Entomology, U.S.A., and the Bulletin dealing with his investigations on the *Anatomy of the Honey Bee*, published in 1910, is well known to Entomologists. The present volume, intended originally as a revision of that bulletin, has been considerably extended to embrace the more recent views on the physiology, behaviour, and embryology of the bee. It is a scientific treatise of importance, not only to the entomologist but to everyone interested in the science of Bee-keeping. We do not think, however, considering the detailed anatomical descriptions and the numerous technical terms used in the text, that it will appeal to the general practical bee-keeper. In view of the high standard of the work from the entomological point of view and the information which it contains, the general introductory paragraphs to certain chapters appear to be somewhat weak, *e.g.* pp. 11, 108.

The chapters on the physiology of digestion and respiration afford the reader an interesting survey of the present state of our knowledge on these questions.

The volume is well produced, and the absence of typographical errors indicates careful proof-reading.

The author has a good style and writes with clearness and precision, and the excellent figures are evidence of his skill as an artist.

James Davidson.

MEDICINE

Rejuvenation by Grafting. By Dr. Serge Voronoff. Translation edited by Fred. F. Imianitoff, B.A. [Pp. 224, with 38 illustrations.] (London: George Allen & Unwin. Price 15*s.* net.)

Dr. Voronoff in this book gives a very clear and detailed account of his experiments and observations on the effects of testicular grafting. As a result of many experiments upon animals Voronoff was convinced that the testes, as a whole, exerted a powerful stimulant action upon the body, and that in cases where the testes had begun to atrophy or were for any reason not able to exert their normal effect, this influence could be restored to the body by suitable grafts. Suitable grafts are those made from the organs of animals of the same species, or, as in the case of chimpanzee grafts into humans, of closely allied species; "foreign" grafts disappear rapidly, being soon absorbed. It is generally assumed that all grafts will sooner or later be absorbed, though in this respect it is of interest to record that, using an improved technique, Voronoff has evidence of grafts persisting after several years. He criticises the Steinach method of "rejuvenation," since his observations have led him to the view that the interstitial cells alone are not the source of the stimulating action which is, in his opinion, the function of the whole gland.

In this book are collected the observations of his widely discussed method on his cases, now some fifty-three in number, papers by colleagues as to the fate of the grafts and as to the precise surgical technique. The results claimed in many cases are remarkable, and are evidently worthy of serious attention; but more cases must be investigated, and over longer periods, before it is possible truly to estimate the value of this method of treatment. In any case, this work gives exceedingly useful information of great practical value on the technique of grafts.

W. C. Cullis.

Internal Secretion and the Ductless Glands. By Swale Vincent, LL.D., D.Sc., M.D., M.R.C.S., L.R.C.P., F.R.S. (Edin.), F.Z.S. [Pp. xv + 463.] (London: Edward Arnold & Co., 1922. Price 25*s.* net.)

In this third edition of Professor Swale Vincent's book we recognise afresh and appreciate the application of the author's keen critical faculty to the study of the problems of the internal secretions of the body. No function of the body has appealed more to the popular imagination than this of the ductless glands, which truly is wonderful enough to justify that appeal. This popular interest has, however, led to the wide support of a number of unjustifiable claims, and we welcome, therefore, all the more warmly this appraisement of present knowledge of the subject by one who, having worked considerably in this field, demands for his own work and for that of others that it shall be supported by unequivocal evidence before being accepted.

It is satisfactory to note that in this new edition, in response to numerous requests, a selected bibliography, which was omitted from the second edition, has again been included. The book has been brought thoroughly up to date, which is no light task, having regard to the volume of matter which appears each year on the subject, and which needs so much knowledge and discrimination in its selection. The chapter on the pancreas, in view of the new work on insulin, has been considerably enlarged, as has also the one on the reproductive organs, which includes consideration of the work of Steinach and Voronoff. In the section on diabetes attention is rightly drawn to the importance of dieting, an essential aspect of treatment which, in the first flush of enthusiasm roused by the work of the Toronto School, was in danger of being neglected. Clearly it is in the best interests of the patient that a treatment which involves daily injections continuing over prolonged periods, perhaps for a whole lifetime, should only be resorted to when all other methods are shown to be of no avail. The final chapter on organ-therapy is again a timely one, demanding more precise and more controlled modes of study of this form of medication before its value, and still more its extent of application, can be regarded as established. This is the more necessary in view of the discrepancy between the results which it is claimed follow the therapeutic administration of various tissue preparations and those obtained with the same materials under the controlled conditions of laboratory investigations.

W. C. Cullis.

A Textbook of Physiology. By H. E. Roaf, M.D., D.Sc., M.R.C.S., L.R.C.P. [Pp. viii + 605, with 318 figures.] (London: Edward Arnold & Co., 1924. Price 25*s.* net.)

Professor Roaf's Textbook of Physiology is one which arouses interest from the moment of reading its preface and contents page, where it is at once seen that he has departed from the usual order of dealing with the different functions of the body. He has made new and unusual combinations and considers the subject as a whole as separating itself into four main divisions. In the first part he deals with the mechanical aspects, and in this he includes a consideration of the skeleton, the action of the muscles, of the mechanism of the circulation, and finally of cellular mechanics. In his second part he discusses the chemical aspects of the body's functions, including under this heading a study of the laws of solutions, homogeneous and heterogeneous systems, and of the chemistry of the urine, the digestive processes, of respiration, and of general metabolism. The third part deals with what are called the regulative mechanics, and embraces a study of the nervous system, the special senses, temperature control, metabolism as a whole, and concludes with a chapter on the regulation of the mind. Part four, under the heading of the maintenance of the individual and the reproduction of the species, deals with nutrition, reaction to environment, heredity, reproduction, and growth.

From this short summary the unusual arrangement of the subject-matter of a textbook on physiology will be clear. It is as though, in the study of a complicated but continuous pattern where the vertical lines and divisions have been stressed, a new observer comes and points out that the lines and divisions can be equally clearly seen running in the horizontal direction. Whatever draws attention to the most wonderful aspect of the human body, its unity or "one-ness," produced as this is by the co-ordination and correlation of its myriad activities, is to be welcomed, and Professor Roaf's presentation of the subject helps to a further realisation of this great fact. This freshness of point of view is one which perhaps will be more appreciated by those who have read and studied along the more conventional lines than by the beginner, and the new grouping undoubtedly leads to a certain amount of repetition and in some cases even to a lack of clearness. A book, however, written in such a way as to allow of the manifestation of an original and forceful point of view cannot fail to be stimulating to those students who choose it as their introduction to the study of physiology, and such a one is this new textbook by Prof. Roaf. W. C. Cullis.

An Introduction to Recent Advances in Comparative Physiology. By Lancelot T. Hogben, M.A., D.Sc., F.R.S. (Edin.), and Frank R. Winton, M.A. [Pp. vii + 242.] (Glasgow: W. Collins, Sons & Co. Price 25*s*. net.)

This book gives a most fascinating and interesting account of some of the findings of the newer and deeper study of biological problems. The older type of study, classificatory as it was in the main, was based largely on the observation of visible form; but, necessary as it was, it must be admitted that, to the general student of life, it is transcended far in interest by the newer and more physiological way of approach. The authors have written a book which will interest not only those whose lines of scientific investigation and study have followed paths other than the biological, but will have at least an equal appeal to those whose studies have not been in the realms of pure science. The list of chapters giving the subjects dealt with in the book, including as they do matters such as The Development of the Individual, Behaviour in Animals, Hereditary Transmission, and The Material Basis of Inheritance, already promise abundant interest, a promise splendidly fulfilled in the actual reading. This is a book which should be read by all those—and their number is steadily increasing—who wish to have some knowledge of the fundamental facts of biology with their obvious bearing on the understanding of the problems of life. The value of the book is enhanced by the fact that the authors are themselves workers in the field of biological research. Readers will not only gain for themselves much fascinating information, but will secure hours of the keenest enjoyment. W. C. Cullis.

The Great Plague in London in 1665. By Walter George Bell, F.S.A., F.R.A.S. [Pp. x + 374.] (London: John Lane; New York: Dodd, Mead & Company. Price 25*s*. net.)

Our review of this work, which was first published in 1924, has been unfortunately delayed. Defoe's well-known book was really merely one in which the author selected episodes and pictures for the purpose of writing a romance and not history. Mr. Bell has set himself quite another task, namely to write a correct history. The work is packed full of information and is illustrated with many excellent plates. The descriptions of old London with its wooden houses, doubtless swarming with rats and enclosing immense accumulations of every kind of filth, gives a picture of insanitation which will be of use to all sanitarians. The author, not a medical man, is to be congratulated upon the intelligence, enthusiasm, and labour which he has expended upon his task. The statistics are intelligently criticised and summarised; and I notice that the curve of mortality given opposite page 238 is precisely one of the curves which are generated by my theoretical equations of epidemics published by the Royal Society (A. Vol. 92, 1916 and, with Hilda P. Hudson, in A. Vol. 93, 1917). Mr. Bell has placed the medical profession and indeed the world under a debt of gratitude to him for this fine work, which is really a most important contribution to the history of epidemics and, therefore, to the history of civilisation. R. Ross.

ENGINEERING

Small Electric Generating Sets. By W. Wilson, M.Sc., B.E., M.I.E.E., A.Am.I.E.E. [Pp. 161, with 60 figures.] (London: Ernest Benn, 1924. Price 18*s.* net.)

The work embraces the design, arrangement, and application of small self-contained generating plants for various purposes.

The various components of an installation are described in some detail, an elementary review of principles being given where desirable, such as the "Electrical Current," "Secondary Batteries," "Two- and Four-stroke Cycles," etc. The general assembly and inter-relation of prime movers, generators, switchboards, and starting devices is very fully considered, from engineering, installation, and economic points of view.

In addition to considering the latest developments in fully automatic apparatus and the light portable sets for cinema and X-ray work, the author has covered all the usual types in use at the present time. In all cases a representative installation is described and illustrated as an example. In this respect the fact that the products of some fifteen to twenty makers has been described is of value.

The treatment is to a large extent descriptive and well illustrated, and forms an adequate summary of present practice.

Although the technical aspects of design are not given undue prominence they are sufficiently indicated to enable the reader to proceed to a sound judgment as to which type to recommend in any particular case.

A. N. Jackson.

Industrial Electricity. Part I. By Chester L. Dawes, S.B. [Pp. xiv + 371, with 241 figures.] (London: McGraw Hill Publishing Co., 1924. Price 11*s.* 3*d.* net.)

In introducing this work the author submits it as being suitable for non-collegiate students. This purpose is reflected in the limitation of mathematical and theoretical treatment to a minimum consistent with clearness.

The initial chapter on elementary magnetism provides a basis on which to build up a sequence of chapters covering electric and magnetic currents, batteries, instruments, etc., and concluding with consideration of the principles and performance of D.C. motors and generators. In the final chapter some space is devoted to automobile lighting sets. This latter item is restricted to one single system of American origin.

The general treatment is clear and well presented, each chapter being supported by examples, problems, and illustrations, while an index is provided.

A minor disadvantage is the use of American technical terms.

On the whole, the work forms an adequate link between physics laboratory and industrial electricity suitable to the class of student for whom it is intended.

A. N. Jackson.

Radio: Beam and Broadcast. Its Story and Patents. By A. H. Morse, A.M.I.E.E., M.I.R.E. [Pp. 192, with 29 + xxx figures and illustrations.] (London: Ernest Benn, 1925. Price 12*s.* 6*d.*)

As is indicated by its title, this book deals mainly with two specific branches of radio communication, and is in no sense a general radio textbook. The author gives not a theoretical or mathematical treatment of the subject, but an historical survey of each branch viewed particularly from the aspects of the patents that have been taken out relating primarily to these branches. In chapter i, however, the early evolution of radio is traced year by year up to 1912, references to the chief patents being given, with extensive extracts in some cases. Sundry selected patents of later date than 1912 are grouped for consideration in chapter ii, while chapter iii, from a discussion of what has already been accomplished, suggests possible future developments.

Chapter iv is entitled "The Poulsen Arc," and the reason for its inclusion is a little hard to find. It seems to serve no particular purpose beyond a separation between the essentially historical part of the book and the remaining five chapters, which deal with Broadcasting and with Beam Transmission in particular, and in conjunction therewith the use of the triode valve for transmission and reception.

Although this volume was written apparently only a few months ago, the author does not appear to be greatly impressed by the possibilities of short-wave communication, either with or without "beam" reflectors, for anything beyond short-distance signalling at night. No mention is made of the improvement in the daylight range of these waves by choice of suitable wave-length; nor of the consequent possibility of the use of this system to give a twenty-four-hour service (at various short wave-lengths) even over ranges of thousands of miles.

With regard to Broadcasting, the author chiefly stresses its great educational value, and especially also its effect on the pronunciation of the language. The possibilities of guided "broadcast" or radiophone transmission, with very high frequency waves to guide the lower frequency carrier, he expresses by the following parody:

> So, engineers, observe a wave
> Hath smaller waves that on him ride,
> And these have smaller waves that ride 'em,
> And so proceed *ad infinitum.*

Nearly one-half the book consists of an appendix containing full texts and extracts from the most important British and United States patents referred to in the earlier chapters, while a very useful bibliography of the literature relating to these two branches of radio is also given.

Primarily the whole book is a considered survey of the radio patent situation, and as such cannot fail to be of value to everyone whose work brings him into touch with radio development. PHILIP R. COURSEY.

Electrical Engineering. By L. A. Hazeltine, M.E. [Pp. xvi + 625.] (New York: The Macmillan Company, 1924. Price 30*s.* net.)

IN placing before the engineering student a general textbook the author enters a congested field, justifying himself by novelty of treatment.

Opening with a chapter on "Fundamental Physical Relations," one passes through consideration of simple electric properties, electro-statics, magnetism, etc., to alternating currents, transient phenomena, and the conductive properties of gases and electrolytes.

On this sound foundation is built the treatment of instruments, measurements, and the design of static and rotary apparatus.

The final chapters complete the syllabus with transmission and distribution, and the modern development of communication.

At the beginning the text is overloaded with analogies which, however, are invariably followed by a sound mathematical proof. In general the work is complete and comprehensive, and is particularly valuable in that special care has been given to sections of the subject not usually enlarged upon in textbooks. Thus chapters on electrostatics, transients, conductivity in gases, and communication are very complete and are considered from the engineering point of view as distinct from that of pure physics.

As a whole the book is well written, adequately illustrated and indexed, while a series of representative exercises is incorporated with each chapter.

A. N. JACKSON.

Magnets. By Charles R. Underhill. [Pp. xiii + 468.] London: McGraw Hill Publishing Co., 1924. Price 20*s.* net.)

"To treat broadly the general principles of apparatus electromagnetically operated and controlled, but particularly to treat electromagnets and permanent magnets in detail." This object is undoubtedly achieved, although the treatment is principally on the heavy engineering side.

In pursuing his goal the author has neglected purely theoretical treatment, particularly mathematics, with resulting lack of clearness in statements and fundamental definitions. Thus we quote " . . . a direct current shunt magnet is allowed time for the continuous voltage to accelerate the electricity in the coil. . . ." The use of American terms is also noticeable.

Chapter iv brings us to firmer ground with general considerations of design, application, and performance. Subsequent chapters deal with Protective Relays, Operation Characteristics, etc., particularly noteworthy being those on Solenoids with Plungers, and General Characteristics and Approximate Rules.

Chapter xvi, Magnet Circuits and their Phenomena, is out of sequence, and would be better placed before the more practical chapters.

The consideration of Alternating Current Apparatus is well presented, but lack of mathematical treatment is again to be regretted.

In general the volume is carefully compiled, well printed, and illustrated, and should prove of service as a book of reference.

A. N. JACKSON.

MISCELLANEOUS

The Metaphysical Foundations of Modern Science. By Edwin Arthur Burt, Ph.D. [Pp. x + 349.] (London: Kegan Paul, Trench, Trübner & Co., 1925. Price 14*s.* net.)

IT is one of the inevitable consequences of early specialisation in science that the abstract implications of scientific method tend to be neglected. Centuries ago the whole study of Nature and the Universe was largely virgin soil. Science was philosophy, and embraced everything. The student of Nature and of natural phenomena brought within his ken a contemplation upon animate and inanimate, and upon the heavens and the earth and the waters under the earth. If the stream of knowledge was shallow, it was at least broad. To-day the position is very much reversed. We hear much nowadays of the "man of science"; but let us be frank. The man of science, using the term in its broadest sense, is necessarily a rare person. The onward march of knowledge has carried us to a stage when the average so-called student of science is in fact only a student of one special aspect. He is no longer a philosopher; he is a chemist, or a microscopist, or a bacteriologist, or an entomologist, or a botanist, or some other "ist." Too often he knows very little of the many other "ists." There are, of course, notable exceptions—men of science in the true, broad sense of the term, who, with their deep, specialised knowledge of one branch or other of the sciences, yet have a sufficiently deep acquaintance with science in general such as equips them with ability to cope with those larger and wider problems of knowledge which ultimately must link up all the sciences into a generalised whole.

This is not the place for a discussion as to the causes for this state of affairs. The facts are definite enough. How many students leave our universities to-day, duly graduated in science, without an attempt either on the part of themselves or their tutors to have impressed upon them an understanding of the logical basis of the "scientific mode of thought" and of the problems of the evolution of knowledge from abstract conceptions? Fortunately there is some evidence in the efforts of Karl Pearson, Whitehead, and others of an attempt to provide the means for remedying this state of affairs. The present volume under review is another instance of this. Prof. Burtt differs from the other writers in this field in that his problem is attacked not from the point of view of a systematised study of scientific method, but purely from the historical standpoint of the gradual evolution of the Newtonian philosophy from its predecessors.

In his very readable volume, the author asks the question, " Why is the main stream of modern thought what it is ? " He proceeds to develop his answer in the light of the evolution of modern physical science. Regarding as the most fundamental possession of an age the ultimate picture it forms as to the nature of its world, Prof. Burtt carries us step by step through the various stages of the revolution of thought from the mediæval scheme whereby man was in every sense the centre of the universe—so that the world of philosophy was expressed in terms of substance, essence, matter, form, quality and quantity—to the modern standpoint that " Nature holds a more independent, more determinative, and more permanent place than Man "—finding its philosophical expression in terms of space, time, mass, energy, and so on. In most interesting fashion we are carried on from Copernicus to Newton, and the metaphysical implications of each stage in physical evolution are laid before us.

The author has accomplished his self-imposed task well, and as a result we have a very welcome addition to the well-known International Library of Psychology, Philosophy, and Scientific Method series. To those who desire to broaden their scientific equipment this historical study can be most unreservedly recommended. It will help them to realise that between science and philosophy there is not a gulf, but a relationship that all must ultimately face who aspire to the true title of " man of science."

I. B. H.

The Isles of Wisdom. By ALEXANDER MOSZKOWSKI. [Pp. v + 322.] (London: George Routledge & Sons, 1924. Price 7*s*. 6*d*. net.)

SEVERAL German gentlemen are visited by a rich American and his beautiful daughter, who offer to place their yacht at the disposal of the former in order to find certain wonderful islands in the Pacific Ocean where civilisation has been carried to a high point. They all start out together and reach the promised lands. They discover that the inhabitants knew all about their coming by means of wireless and were ready to afford them full information about themselves. They visit the Platonic Island, the Island of Happy Conditions, the Island of Perversions, the Mechanist Island, the Reactionary Island, the Island of Fine Arts, certain " intermediate - islands," and others. During all these voyages and adventures they talked German philosophy. We advise purchase of the book, but doubt whether the Anglo-Saxon will do much more than skim through the innumerable discussions ; though even with such perfunctory reading he will find many interesting propositions and arguments. But we fear that whatever philosphers may say the world will be conducted on the principles, not of philosophy, but of a very powerful lady called Nature. She has probably done the best for us she can and is watching with some amusement our petty efforts to escape from her rule.

R. ROSS.

Problems of Personality. Studies Presented to Dr. Morton Prince, Pioneer in American Psychopathology. Board of Editors, C. MacFie Campbell, M.A., B.Sc., M.R.C.P., M.D., and four others. [Pp. xiii + 434.] (London: Kegan Paul, Trench, Trübner & Co., 1925. Price 18*s*. net.)

A collection of twenty-four essays made in honour of Dr. Morton Prince, by distinguished psychologists and medical men, with a bibliography of Dr. Prince's writings. The first essay is by Dr. G. Elliot Smith, F.R.S., who summarises his views on the evolution of the human brain. There are six essays on psychoanalysis, *pro and con*. Many of the contributors are well-known workers in the line of psychology.

Airs for the Hautbois and other Instruments. Written by E. N. DA C ANDRADE. [Pp. 68.] (London: Cecil Palmer, 49 Chandos Street, W.C.2, 1924. Price 3*s.* 6*d.* net.)

THE author of this book is well known and much appreciated on the physical side of science, and formerly used to contribute largely to SCIENCE PROGRESS. He has now fallen (or shall we say risen ?) into writing an excellent little book of poems. He calls himself a " poet of London, or if that be denied a natural philosopher, or if that be not allowed yet (almost as rare a title) one who earns his living honestly." There is a witty foreword, and all the verses are very good. We like best *The Little Dance* and *The Boy and the Birds*. Our only wonder is that when Science writes poetry she does not write poetry more often about her own interests. Anyone can sing regarding flowers, butterflies, and maidens. Really the war of science is a great conflict full of great episodes, and yet our poets of science (of whom there are not a few, including the President of the Royal Society) are generally silent regarding this tremendous and novel epic of the gods. R. ROSS.

The Growth of the Mind. By PROF. K. KOFFKA. [Pp. xvi + 383.] (London: Kegan Paul, Trench, Trübner & Co. Price 15*s.* net.)

THE aim of this work is to expound, chiefly to school teachers, certain of the principles of the *Gestalt-Theorie* in psychology and their implications in the interpretation of child development. It is therefore of interest to a wide circle of child lovers and child students. The author points out that to understand a child's behaviour it is necessary not only to study his reactions " from without " in a critical manner, but since every act of behaviour is an expression of an individual dependent on his entire constitution, it is necessary to attempt to study him " from within." " To understand the child we must know his reactions, to understand his reactions we must also know the child."

The earliest beginnings of consciousness are supposed to be the appearance of specific qualities on an ill-defined background, such qualities constituting the simplest mental configurations. A very young infant appears first of all to perceive and pay attention not to simple sensations, but to quite complicated stimuli such as the human voice and the human face. Recognition rapidly develops into discrimination, and the child reacts quite differently to familiar persons and to strangers. Situations are viewed as a whole, so that the mental configuration excited by the sight of, say, a stick is quite different once a stick has been used to secure some desired end ; from being an indifferent object it becomes a potential instrument. Mental development is " not the bringing together of separate elements, but the arousal and perfection of more and more complicated configurations in which the phenomena of consciousness and the functions of the organism go hand in hand." The pleasure taken in an achievement operates as an incentive to new achievements. This question is considered in relation to experiments on children and animals and is one not to be overlooked by any who have to apply mental tests. Not only is the co-operation of the subject essential, but for an accurate diagnosis the observer must envisage the situation from the standpoint of the child's world.

Special chapters deal with problems of number and language, the author agreeing with Stern that the discovery by a child that everything has a name is the most important of his life. The section on the " World of a Child " should be read by anthropologists as well as teachers. The author points out that it is incorrect to speak of a propensity to personification as if children first had perceptions like our own, and afterwards endow them with life from the analogy of their own experience. Children and primitive men perceive certain things differently, the primitive finds characteristics in things whereby they are for him perceptually connected, though we may call the connections mystical. The development of perception depends upon the total environment and especially upon the social conditions. The play-world for a child for long remains separate from the adult-world, and then is more or less suddenly discarded. F. C. SHRUBSALL.

Studies in the History of Mediæval Science. By CHARLES HOMER HASKINS. [Pp. xiv + 411.] (Oxford University Press, for Harvard University Press. Price 28*s.* net.)

THE Department of History of the Harvard University is rightly famed for its many activities, and some thirty volumes of studies have thus far been issued under its ægis. It is an eloquent testimony to the manner in which the narrow boundaries of the historical student of past decades have been broadened that this present volume by Prof. Charles H. Haskins deals with Mediæval Science. Prof. Haskins is well fitted for his task. Historical research has already been enriched by his contributions extending over a period of many years, and as a general historian of world-movements he presents in this volume a viewpoint that brings mediæval science into relationship with the general story of the influence of Eastern culture upon Western Europe. In this respect, therefore, Prof. Haskins in no way encroaches upon the ground covered by Lynn Thorndyke in his recent notable work, recently reviewed in these pages.

The period embraced in these studies is that of the twelfth and thirteenth centuries. The aim of the author is to contribute materials for the achievement, yet to come, of a comprehensive history of European science in the Middle Ages. This, he points out, must embrace two aspects, namely, the recovery and assimilation of the science of antiquity, and the beginnings of observational and experimental science. Towards this end the book opens with a review of the Spanish schools of Arabic translation, and of the contributions to mediæval science of Adelard of Bath, Hermann of Corinthia (not to be confounded with Hermann the Cripple of an earlier period), and Hugo Sanctallensis. Our author then passes on to a survey of the twelfth-century writers on Astronomy and Mathematics by whose influence the teachings of Aristotle and Ptolemy were spread, and of the work of Robert of Chester, Roger of Hereford, and others in spreading the new culture in England. We are now carried to the Greek phase of the mediæval renaissance, when direct contact with Greek sources without the intermediary of Arabic learning was established. As opening up a field but little explored hitherto, chapter viii is particularly welcome. Here attention is drawn to the forces of history, under the Norman régime, that gave such centres as Palermo and Salerno their cosmopolitan character, whereby Greek, Latin, and Arabic civilisation maintained a harmonious contact. This, together with the presence of large libraries, was bound to react favourably towards scholarship, and the manner of this reaction in producing the Hellenists of the twelfth century is ably told. So the book passes on to that fruitful period of scientific encouragement at the hands of Frederick II and his astrologer, Michael Scot.

Professor Haskins's book is a scholarly work that must inevitably take its place among the standard works on mediæval studies. It is well written and well produced and is completely indexed. We recommend it without reserve to all mediævalists. I. B. H.

The Mechanical Investigations of Leonardo da Vinci. BY IVOR B. HART, B.Sc., PH.D., ETC. [Pp. vii + 235, with 136 illustrations.] (London: Chapman & Hall. Price 16*s.* net.)

No physicist's library should be without a copy of this scholarly work, which, from a careful study of the voluminous notes of Leonardo da Vinci, gives us not only some measure of his remarkable genius, but also a wealth of observation and material well worthy of consideration, especially on the subject of flight. Moreover, quite apart from the conclusions at which Leonardo arrived, his scientific outlook and methods of observation and experiment are so essentially modern as to be a standing example for all time. The dimension of time does not enter into the evaluation of genius. Dr. Hart is to be thanked for having made such valuable material so pleasantly accessible to English readers.

W. C. B.

Scientific Method. Its Philosophical Basis and its Modes of Application. By F. W. WESTAWAY. Third edition, with new applications. [Pp. xxiv + 456.] (London: Blackie & Son, 1924. Price 10*s*. 6*d*. net.)

MR. WESTAWAY has attempted the praiseworthy task of writing a general introduction to the study of the philosophical and logical problems of scientific method. Considering the complexity and difficulty of the enterprise, Mr. Westaway may be congratulated on the measure of success which he has achieved. The mere fact that his book is in its third edition shows that it has met a real need, and is duly appreciated.

The volume is divided into five Books, entitled respectively: (1) "The Philosophy of Scientific Method," pp. 1–164; (2) "The Logic of Scientific Method," 165–302; (3) "Famous Men of Science and their Methods," 303–368; (4) "Scientific Method in the Classroom," 369–414; (5) "Further Applications," 415–56. The author has his eye mainly on the teacher of science and his opportunities of imbuing the rising generation with the spirit of science. Mr. Westaway's conception of scientific method, and of the way to master it, is one with which most people will agree. "If the young teacher desires to master scientific method, he must follow the history of science, and see how one faulty method has been superseded by another, which, in its turn, has itself been superseded, so difficult has it been to discover the principles of the true method; he must learn to get at the exact meaning of all his terms; he must learn to eliminate all personal bias from his facts; he must ever be on his guard against hasty generalisations; he must ever be ready to give up a pet hypothesis, once the facts are against him, and he must never allow his hypotheses to masquerade as facts; he must acquire a knowledge of inductive reasoning; he must learn to balance probabilities; he must remember that even the best conclusions of science are never more than in a high degree probable; and he must study the original records of successful investigators." Mr. Westaway's book was meant to help in all these things. But to attempt all these things in one volume naturally necessitated selection, and, therefore, omissions. No wonder that some of the most important of modern methods of science are not even mentioned. This may appear regrettable in a volume intended to spread the gospel of scientific method. But then, it only professes to be a first introduction to the subject. More serious perhaps is the possible criticism that the volume includes too much. It seems to combine a sketch of the history of philosophy, an inductive logic, a history of scientific method, an anthology from the history of science, and a guide to scientific pedagogy! Moreover, the method of exposition, the citing of passages from numerous authors, almost invites the suggestion that Mr. Westaway has given us his commonplace book, with the favourite passages duly arranged and linked together. The beginner may be rather embarrassed by such superabundance, and find it hard to see the wood for the trees. For the beginner, it might have been better if Mr. Westaway had let himself go rather more, and had given a free, systematic account of his own views on the various subjects. However, we must be grateful for what he has given us—practically a source-book on the subject.

A. WOLF.

BOOKS RECEIVED

(Publishers are requested to notify prices)

Le Principe de Symétrie et ses Applications. Par F. M. Jaeger. Traduit de l'Anglais par Pierre Gerald et Jean Chevrier. Preface de M. Charles Moureu. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins. (Pp. 417.) Price 55 frs.

Mémorial les Sciences Mathématiques. Publié sous le Patronage de L'Académie des Sciences de Paris. Fascicule II par G. Valiron, Fascicule III par M. Paul Appell. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1925. (Pp. 56 and 74 respectively.) Price 10 frs. each.

Introduction Géométrique a la Mécanique Rationale. Par Charles Cailler, Professeur a l'Université de Genève. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1924. (Pp. xii + 628.) Price 60 frs.

Calcul des Probabilités. Leçons professées à la Faculté des Sciences de Paris. Par M. Émile Borel. Rédigées par René Lagrange. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins. (Pp. 160.) Price 18 frs.

Mécanique Statisque Classique. Leçons professées à la Faculté des Sciences de Paris. Par M. Émile Borel. Rédigées par Francis Perrin. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins. (Pp. 148.) Price 18 frs.

Calculus of Variations. By Gilbert Ames Bliss, Professor of Mathematics. The University of Chicago, Chicago. Illinois: The Open Court Publishing Company. (Pp. xiii + 189.) Price 10*s.* net.

Practical Astronomy. A Textbook for Engineering Schools and a Manual of Field Methods. By George L. Hosmer, Associate Professor of Geodesy, Massachusetts Institute of Technology. Third Edition. New York: John Wiley & Sons; London: Chapman & Hall, 1925. (Pp. xi + 270, with 80 figures.) Price 13*s.* 6*d.* net.

A Laboratory Manual of Experiments in Physics. By Leonard Rose, Ingersoll. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4, 1925. (Pp. ix + 220.) Price 10*s.* net.

Electricity and the Structure of Matter. By L. Southerns, M.A., B.Sc., Lecturer in Physics in the University of Sheffield. London: Oxford University Press, 1925. (Pp. 128.) Price 2*s.* 6*d.* net.

The Crystalline State. By Sir William Henry Bragg, K.B.E., D.Sc., F.R.S., The Romanes Lecture, delivered in the Examination Schools, May 20, 1925. Oxford: at the Clarendon Press, 1925. (Pp. 31.) Price 2*s.* net.

An Introduction to Fluid Motion. By W. N. Bond, B.A., B.Sc., D.Sc., A.R.C.S., F.Inst.P., Lecturer in Physics, University College, Reading. London: Edward Arnold & Co., 1925. (Pp. 94.) Price 5*s.* net.

Die Theorien der Radiologie, Handbuch der Radiologie. Band VI. Bearbeitet von M. v. Laue, P. Zeeman, H. A. Lorentz, A. Sommerfeld und G. Wentzel, Georg Joos, E. Riecke, L. Vegard, P. Debye. Mit 141 Figuren and Abbildungen im Text und auf Tafeln. Leipzig: Akademische Verlagsgesellschaft, M.B.H., 1925. (Pp. xi + 807.) Price 40 marks.

The Structure of Light. The Fison Memorial Lecture. 1925. By Sir J. J. Thomson, O.M., Master of Trinity College. Cambridge: at the University Press, 1925. (Pp. xii + 38.) Price 2*s.* 6*d.* net.

The Spectroscopy of X-rays. By Manne Siegbahn, Professor in the University of Upsala. Translated, with the Author's Additions, by George A. Lindsay, Assistant Professor of Physics in the University of Michigan. London: Oxford University Press, 1925. (Pp. xii + 287.) Price 20*s.* net.

Organic Syntheses. An Annual Publication of Satisfactory Methods for the Preparation of Organic Chemicals. Oliver Kamm, Editor-in-Chief of Board of Five, together with fifteen Contributors. Vol. iv. New York: John Wiley & Sons; London: Chapman & Hall, 1925. (Pp. vii + 89.) Price 4*s.* 6*d.* net.

The Technology of Wood Distillation. With Special Reference to the Methods of Obtaining the Intermediate and Finished Products from the Primary Distillate. By M. Klar. Translated by Alexander Rule, M.B.E., D.Sc., Ph.D., F.I.C. With an Additional Chapter by the Translator. London: Chapman & Hall, 11 Henrietta Street, 1925. (Pp. xv + 496.) Price 25*s.* net.

A System of Physical Chemistry. By William C. McC. Lewis, M.A., D.Sc., Professor of Physical Chemistry in the University of Liverpool. In three volumes. Volume I, Thermodynamics. Fourth Edition. London: London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. viii + 489.) Price 15*s.* net.

A Summary of Physical Chemistry. By Professor K. Arndt. Translated from the Fourth German Edition by W. H. Patterson, M.Sc. London: Methuen & Co., 36 Essex Street, W.C. (Pp. 92.) Price 3*s.* 6*d.* net.

Blacks and Pitches. By K. M. Langton, M.A., B.Sc., A.I.C., Director, Messrs. J. B. Walker & Co., Hull. London: Ernest Benn, 8 Bouverie Street, E.C.4, 1925. (Pp. xi + 179.) Price 15*s.* net.

Cellulose Ester Varnishes. By F. Sproxton, B.Sc., F.I.C. (British Xylonite Co.) London: Ernest Benn, 8 Bouverie Street, E.C.4, 1925. (Pp. xi + 178.) Price 15*s.* net.

Non-Metallic Minerals. Occurrence-Preparation-Utilisation. By Raymond B. Ladoo. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4, 1925. (Pp. viii + 686.) Price 30*s.* net.

Engineering Geology. By H. Ries, Ph.D., Professor of Geology in Cornell University, and Thomas L. Watson, Ph.D., Professor of Geology in the University of Virginia and State Geologist of Virginia. Third Edition, Revised. New York: John Wiley & Sons; London: Chapman & Hall, 1925. (Pp. vii + 708, with 253 figures.) Price 25*s.* net.

An Introduction to Physical Geology. With Special Reference to North America. By William J. Miller, Professor of Geology, University of California. London: Chapman & Hall, 11 Henrietta Street, W.C.2., 1925 (Pp. xvi + 435, with 351 illustrations.) Price 13*s.* 6*d.* net.

A Textbook of General Botany. By William H. Brown, Ph.D., Director, Bureau of Science, Manila; and Professor of Botany, University of the Philippines. London: Ginn & Company. (Pp. xi + 484, with 518 figures.) Price 13*s.* 6*d.* net.

A Class Book of Botany. By Ernest Stenhouse, B.Sc., Associate of the Royal College of Science, London. London: Macmillan & Co., 1925. (Pp. xi + 514.) Price 7*s.* 6*d.* net.

The Vegetation of Burma. From an Ecological Standpoint. By L. Dudley Stamp, B.A., D.Sc., A.K.C., F.G.S., I.E.S., Professor of Geology and Geography in the University of Rangoon and Calcutta. Thacker, Spink & Co., 1925. (Pp. 38, with 12 figures and 28 plates.) Price 7*s*.

Evolution, Heredity, and Variation. By D. Ward Cutler, M.A., F.L.S., Chief Protozoologist to the Rothamsted Experimental Station, Harpenden. London: Christophers, 22 Berners Street, W.1. (Pp. 147.) Price 3*s*. net.

Chimpanzee Intelligence and its Vocal Expressions. By Robert M. Yearkes and Blanche W. Learned. Baltimore: The Williams & Wilkins Company; London: Bailliere, Tindall & Cox, 8 Henrietta Street, W.C.2. (Pp. 157.) Price 17*s*. 6*d*. net.

Concerning Evolution. By J. Arthur Thomson, M.A., LL.D., Professor of Natural History in the University of Aberdeen. New Haven: Yale University Press; London: Oxford University Press, 1925. (Pp. xi + 241, with 25 figures.) Price 11*s*. 6*d*. net.

Evolution in the Light of Modern Knowledge. A Collective Work. London: Blackie & Son, 50 Old Bailey, 1925. (Pp. xiv + 528, with 4 plates.) Price 21*s*. net.

A Synopsis of the Amphibia California. By Tracey I. Storer. Vol. xxvii. Berkely, California: University of California Press, 1925. (Pp. iv + 342, with 18 plates.) Price $4.50.

An Introduction to Sexual Physiology. For Biological, Medical, and Agricultural Students. By F. H. A. Marshall, F.R.S. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. xii + 167, with 72 figures.) Price 7*s*. 6*d*. net.

Principles of Psychotherapy. By Dr. Pierre Janet, Member of the Institute, Professor of the College of France. Translated by H. M. and E. R. Guthrie. London: George Allen & Unwin, 40 Museum Street, W.C.1. (Pp. xiii + 233.) Price 10*s*. 6*d*. net.

Food and the Family. By V. H. Mottram, M.A., Professor of Physiology in the University of London. London: Nisbet & Co., 22 Berners Street, W.1. (Pp. xiii + 240.) Price 5*s*. net.

The Fats. By J. B. Leathes, M.A., F.R.S., Professor of Physiology in the University of Sheffield, and H. S. Raper, C.B.E., M.B., Ch.B., D.Sc., Brackenbury Professor of Physiology in the University of Manchester. Second Edition. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. vii + 242.) Price 12*s*. 6*d*. net.

Health and Environment. By Leonard Hill, M.B., F.R.S., Director, Department of Applied Physiology, National Institute of Medical Research, and Argyll Campbell, M.D., D.Sc., Member of Research Staff, National Institute for Medical Research. London: Edward Arnold & Co., 1925. (Pp. xi + 208, with 7 plates.) Price 12*s*. 6*d*. net.

Guy Patin and the Medical Profession in Paris in the Seventeenth Century. By Francis R. Packard, M.D., London: Oxford University Press. (Pp. xxii + 334, with 17 illustrations.) Price 18*s*. net.

Public Health in Theory and Practice. An Historical Review. By William Henry Welch, M.D., LL.D., Director of the School of Hygiene and Public Health, Johns Hopkins University. New Haven: Yale University Press; London: Oxford University Press, 1925. (Pp. 52.) Price 4*s*. 6*d*. net.

A Treatise on Electricity. By F. B. Pidduck. Second Edition. Cambridge: at the University Press, 1925. (Pp. xiv + 664, with 385 figures in the text.) Price 21*s*. net.

Alternating Currents and Transients Treated by the Rotating Vector Method. By F. M. Colebrook, B.Sc., K.I.C., A.C.G.I. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4, 1925. (Pp. x + 195.) Price 15*s*. net.

The Conversion of Coal into Oils. By Dr. Franz Fischer, Authorised English Translation, edited with a Foreword and Notes by R. Lessing, Ph.D., F.G.S. London: Ernest Benn, Ltd., 8 Bouverie Street, E.C.4, 1925. (Pp. 284, with 75 illustrations.) Price 36*s*. net.

Lord Lister. By Sir Rickman John Godlee, Bt., K.C.V.O., M.S., F.R.C.S. Third Edition, revised and reset throughout. (Pp. xvi + 686.) Oxford: at the Clarendon Press. Price 21*s*. net.

Admirably written and revised and reset throughout with many excellent portraits and other illustrations—a classic of surgical science.

Colour-Blindness. With a Comparison of Different Methods of Testing Colour-Blindness. By Mary Collins, M.A., B.Ed., Ph.L., Lecturer on Applied Psychology, Edinburgh University, with an Introduction by Dr. James Drever. London: Kegan Paul, Trench, Trübner & Co., New York: Harcourt, Brace & Company, 1925. (Pp. xxxi + 237.) Price 12*s*. 6*d*. net.

The Psychology of Selecting Men. By Donald A. Laird, Ph.D. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4. 1925. (Pp. xi + 374.) Price 15*s*. net.

Accounting for the Petroleum Industry. By David F. Morland and Raymond W. McKee. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4, 1925. (Pp. viii + 304.) Price 20*s*. net.

Seventh Earl Grey Memorial Lecture. Delivered at King's Hall, Armstrong College, Newcastle-on-Tyne, March 5, 1925. By F. W. Aston, Sc.D., F.R.S. London: Oxford University Press, 1925. (Pp. 23.) Price 1*s*. net.

Proteus, or the Future of Intelligence. By Vernon Lee, Litt.D. London: Kegan Paul, Trench, Trübner & Co.; New York: E. P. Dutton & Co., 1925. (Pp. 63.) Price 2*s*. 6*d*. net.

Cours d'Aviation. Destiné aux Élèves-Pilotes et Mécaniciens. Par A. Desaleux. Avions-Moteurs; Cartes-Météorologie. Paris: Gauthier-Villars et Cie. 55 Quai des Grands-Augustins, 1925. (Pp. 246.) Price 35 frs. net.

Essentials of Scientific Method. By A. Wolf, M.A., D.Litt., Professor of Logic and Scientific Method in the University of London. London: George Allen & Unwin, 40 Museum Street, W.C.1, 1925. (Pp. 160.) Price 5*s*. 6*d*. net.

A Treatise on Light. By R. A. Houstoun, M.A., Ph.D., D.Sc., Lecturer on Physical Optics in the University of Glasgow. Fourth Edition. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. xi + 486, with 334 diagrams.) Price 12*s*. 6*d*. net.

An Introduction to Economic Geography. Volume I. Natural Environment as Related to Economic Life. By Wellington D. Jones, and Derwent S. Whittlesey. Chicago, Illinois: The University of Chicago Press (Pp. xxv + 375, with 366 figures.) Price $5.

A Catalogue of British Scientific and Technical Books, covering every Branch of Science and Technology, carefully classified and indexed. New Edition, entirely revised and enlarged. London: British Science Guild, 6 John Street, Adelphi, W.C.2., 1925. (Pp. xxii + 489.) Price 12*s*. 6*d*. net.

Intermediate Light. By R. A. Houstoun, M.A., Ph.D., D.Sc., Lecturer on Physical Optics in the University of Glasgow. London: Longmans, Green & Co., 39 Paternoster Row, E.C., 1925. (Pp. x + 227, with 162 figures.) Price 6*s.* net.

The Torch-bearers. Vol. II, The Book of Earth. By Alfred Noyes. London: and Edinburgh: William Blackwood & Sons, 1925. (Pp. vii + 375.) Price 7*s.* 6*d.* net.

Lister and His Achievement. Being the First Lister Memorial Lecture. Delivered at the Royal College of Surgeons of England, on May 14, 1925. By Sir Wm. Watson Cheyne, Bt., K.C.M.G., C.B., F.R.C.S., F.R.S. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. 136.) Price 7*s.* 6*d.* net.

The Riddle of the Earth. By Appian Way. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1925. (Pp. xiv + 251, with 13 illustrations.) Price 10*s.* 6*d.* net.

Statistical Methods for Research Workers. By R. A. Fisher, M.A., Fellow of Gonville and Caius College, Cambridge, Chief Statistician, Rothamsted Experimental Station. Edinburgh: Oliver & Boyd, Tweeddale Court; London: 33 Paternoster Row, E.C. (Pp. ix + 239.) Price 15*s.* net.

The Future. By A. M. Low, F.C.S., F.R.G.S., M.I.A.E., Fellow and Member of Council Institute of Patentees. London: George Routledge & Sons, 68 Carter Lane, E.C., 1925. (Pp. 203, with 8 plates.) Price 5*s.* net.

Historic Instruments for the Advancement of Science. A Handbook to the Oxford Collections. Prepared for the Opening of the Lewis Evans Collection on May 5, 1925. By R. T. Gunther. Oxford University Press, 1925. (Pp. 90.) Price 2*s.* 6*d.* net.

Smoke. A Study of Town Air. By Julius B. Cohen, Ph.D., B.Sc., F.R.S., Emeritus Professor of Organic Chemistry in the University of Leeds, and Arthur G. Ruston, B.A., D.Sc., Lecturer in Agricultural Economics in the Department of Agriculture, University of Leeds. New Enlarged Edition. London: Edward Arnold & Co., 1925. (Pp. xii + 108, with 14 plates.) Price 8*s.* 6*d.* net.

Mécanique de L'Aviation. Application des Méthodes de la Mécanique Rationnele à l'Étude du Vol, et de la Construction des Avions. Par Lieutenant-Colonel Alayrac, Professeur à l'École Supérieure d'Aéronautique. Paris: Gauthier-Villars et Cie, 55 Quai des Grand-Augustins, 1925. (Pp. x + 352.) Price 50 frs.

Phases of Modern Science. Published in Connection with the Science Exhibit arranged by a Committee of the Royal Society in the Pavilion of His Majesty's Government at the British Empire Exhibition, 1925. London: A. & F. Denny, 163A Strand, W.C.2. (Pp. vii + 232.) Price 3*s.* 6*d.* net.

The Mind and its Place in Nature. By C. D. Broad, M.A., Litt.D., Fellow and Lecturer in the Moral Sciences. Trinity College, Cambridge. London: Kegan Paul, Trench, Trübner & Co.; New York: Narcourt, Brace & Co., 1925. (Pp. x + 674.) Price 16*s.* net.

Summation of Series collected by L. B. W. Jollet, M.A. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1925. (Pp. xi + 232.) Price 13*s.* 6*d.* net.

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SCIENCE PROGRESS

RECENT ADVANCES IN SCIENCE

PURE MATHEMATICS. By F. Puryer White, M.A., St. John's College, Cambridge.

Finite Groups.—Sylow's theorem, which asserts that every group whose order is divisible by p^m but not by p^{m+1}, p being a prime number, contains a subgroup of order p^m, is usually given very early in a course on finite groups, and thus it is desirable to make the proof as simple as possible. One line of proof is based on properties of the symmetric proof and is given, for instance, in Miller, Blichfeldt, and Dickson, *Finite Groups*, 1916, p. 27. G. A. Miller (*Bull. Amer. Math. Soc.*, **31**, 1925, 253–6) now simplifies this procedure by basing the proof of Sylow's theorem for the symmetric group of degree p^m upon a proof of the fact that S involves a subgroup P of order p^a which is of index prime to p considered as a sub-group of the group formed by the substitutions of S which transform P into itself. The other well-known proof, due to Frobenius, comes naturally considerably later on in the development of the subject.

Permutation Groups.—In a transitive group of order g and of degree n the subgroup G_1 composed of all the permutations of G which omit a given letter is of order g/n. G. A. Miller (*Trans. Amer. Math. Soc.*, **27**, 1925, 137–45) investigates the possible permutation groups which involve a particular G_1. An immediate result is that if G_1 is the symmetric group of degree m, G must be the symmetric group of degree $m + 1$, except in the special case $m = 2$, when G may also be the octic group of degree 4; similarly, if G_1 is the alternating group of degree m, G is the alternating group of degree $m + 1$, except when $m = 3$, when G can also be the group of order 18 and degree 6. A further result is that a given group can only be the G_1 of a finite number of transitive substitution groups. Prof. Miller discusses in particular two cases. In the first, the degree of G_1 is a prime p; it then follows that the degree of G is either $p + 1$ or $2p$. Further, we have the following theorem: the regular group of odd prime degree p is always the G_1 of one and only one transitive group of degree $2p$. In the special case when p is of the form $2^a - 1$ it is also the G_1 of one and only one group of degree $p + 1$. It cannot be the G_1 of any other transitive group. The second case is that in which G_1 is transitive. Particular theorems are that a regular abelian group of degree m cannot appear as the G_1 of a transitive group of degree $m + k$ unless $m/k + 1$ is a prime or the power of a prime, and that we must have $m \overline{<} 2k$.

In another paper (*Amer. Journal of Math.*, **47**, 1925, 176–80), G. A. Miller considers the possible number of different systems of imprimivity which may appear in the imprimitive group of a given degree n. He proves that it is possible to construct an imprimitive group of degree n which shall have exactly as many different systems of imprimivity as there are operators of order 2 in an arbitrary group whose order is any divisor of n, including n; and an imprimitive group of degree n cannot have any other number of such systems of imprimivity. If p is an odd prime and G is of order p^m, the number of its systems of imprimivity such that each system involves p letters is equal to the number of subgroups of order p in a group whose order is a divisor of the degree of G.

Finite Groups of Linear Substitutions.—If G is a group of finite order which contains an operation P of prime order p, permutable only with its own powers, then it follows from Sylow's theorem that the order of G must be $(1 + kp)ps$, where s is a factor of $p - 1$. The greatest subgroup of G which contains self-conjugately the subgroup generated by P must be a metacyclical subgroup $\{S, P\}$, where

$$S^{-1}PS = P^g, \quad S^s = E,$$

g being a primitive root of the congruence $g^s \equiv 1 \pmod{p}$.

If $s = p - 1$, P is conjugate with all its powers and the characteristic of P in each irreducible representation of G is rational. These results are given, for example, in Burnside's *Theory of Groups*, chap. xv. W. Burnside (*Proc. Camb. Phil. Soc.*, **22**, 1925, 788–92) now considers the case in which s is less than $p - 1$. He shows that, except for the case $s = \frac{1}{2}(p - 1)$, $p \equiv 3 \pmod{4}$, there is necessarily a unit-representation of G distinct from the identical representation, and that in this representation P has the characteristic 1. He deduces the following result: if a group G of linear substitutions of finite order, and of degree s, contain the irreducible metacyclical subgroup $\{S, P\}$ generated by

$$P \sim x_i' = \omega^{g^i} x_i \quad (i = 0, 1, 2, \ldots s - 1),$$
$$S \sim (x_0 x_1 \ldots x_{s-1}),$$

where ω is a primitive pth root of unity, s a factor of $p - 1$, and g a primitive root of the congruence $g^s \equiv 1 \pmod{p}$, and if in G the substitution P is permutable only with its own powers, then G contains no other substitution than those of $\{S, P\}$, except in the case already mentioned. The exceptional cases actually exist, and in another paper (*ibid.*, 779–87) the same author shows how to set up a set of linear substitutions on $\frac{1}{2}(p - 1)$ symbols which gives a representation of the modular group of order $\frac{1}{2}p(p^2 - 1)$, p being any prime of the form $4n + 3$. Special cases had been known before, the case $(p = 7)$ for the representation of the simple group of order 168 by linear substitutions on 3 symbols is in all the text-books, and that $(p = 11)$ for the simple group of order 660 had been given by Burnside himself in 1920.

Quadratic Forms with an Infinity of Variables.—The solution of many of the problems of physics can be made to depend upon the simultaneous reduction of two quadratic forms to the sums of squares; a typical example is the case of a dynamical system to which we may apply the method of Lagrange, the kinetic and potential energies being expressed as quadratic forms involving respectively generalised velocities and displacements. In Rayleigh's *Theory of Sound* (vol. i, chap. 6) the vibrations of a stretched string are discussed as a limiting case of the vibrations of a string divided into a number of small parts, the mass of each being concentrated at its centre—a system in which the number of degrees of freedom is finite. In the limiting case the quadratic forms involve an infinite number of variables, and it is thus desirable to develop a theory of infinite quadratic forms and, in particular, to investigate the generalisation of the theorem of Weierstrass that two quadratic forms in a finite number of variables may be simultaneously reduced to the sums of squares if *one* member of the family defined by them is definite and complete (non-singular). This has now been done by J. Hyslop in an important paper, "A Contribution to the Theory of Bounded Matrices and Quadratic Forms with an Infinity of Variables" (*Proc. L.M.S.*, **24**, 1925, 264–304). The author begins with a recapitulation of the symbols employed, following in the main the notation of Riesz. A vector (x) is a system of numbers, real or complex, $x_1, x_2 \ldots$ *ad infinitum*, for which the sum $\sum_1^\infty |x_r|^2$ converges; a matrix is a doubly infinite array of real or complex numbers a_{rs}, it is *bounded* if a fixed constant M exists such that for every positive integer n and for every pair of unit vectors (x), (y), *i.e.* vectors for which $\sum_1^\infty |x_r|^2 = 1$,

$$\left|\sum_1^n a_{rs} x_s y_r\right| \leqslant \mathrm{M}.$$

A matrix defines two linear substitutions

$$\sum_{s=1}^{\infty} a_{rs} x_s = z_r, \quad \sum_{r=1}^{\infty} a_{rs} y_r = w_s,$$

which are written

$$(\mathrm{A})\, x = (z), \quad \mathrm{A}'(y) = (w),$$

where A stands for the matrix and A′ for the transposed matrix, obtained by interchanging rows and columns in A.

A matrix is *symmetric* if it is identical with its transponent, and *Hermitian* if it is identical with the transponent of the matrix obtained by replacing every element a_{rs} by the conjugate complex number; a real symmetric matrix gives rise to a *quadratic form* $\mathrm{A}(x, x) = \sum^{\infty} a_{rs} x_r x_s$, and a Hermitian matrix to a *Hermitian form* $\mathrm{A}(x, \bar{x}) = \sum^{\infty} a_{rs} \bar{x}_r x_s$.

Two vectors (x), (y) are *orthogonal* if $(x, y) = \sum_{1}^{\infty} x_r y_r = o$; a set of vectors is *complete* if no non-zero vector exists orthogonal to all of them. A matrix, substitution, or form A is complete if the vectors of A′ form a complete set. A *characteristic vector* of a substitution A is a vector (x) such that $\mathrm{A}(x) = \lambda (c)$; characteristic vectors of A will only exist for such values of λ as make $(\mathrm{A} - \lambda \mathrm{E})$ incomplete, E being the identical substitution, and these values of λ are the *characteristic numbers* of the substitution.

After these necessary preliminaries, which are the natural extensions of similar ideas for matrices with a finite number of elements, the author proceeds to the consideration of the characteristic properties of the bounded linear substitution. He obtains a theorem of wide application, viz.:

If B, C be two bounded matrices, a necessary and sufficient condition for the existence of a matrix A whose bound does not exceed M, and such that AB=C is that, for every vector (x), $|\mathrm{C}(x)| \leqq \mathrm{M}\, |\mathrm{B}(x)|$. Here $|x|$ denotes the "length" of the vector (x), the positive square root of $\sum_{1}^{\infty} |x_r|^2$.

This theorem is then applied to prove an expansion for the bounded bilinear form

$$\mathrm{A}(x,y) = \sum_{r} \mu_r (p^{(r)}, x)\, (u^{(r)}, y) + \sum_{l,m,n} \int_{\alpha_l}^{\beta} \mu_l(g) \phi_{lm}(g) \phi_{ln}(g)\, dg\, (q^{(lm)}, x)\, (v^{(ln)}, y),$$

wherein $(p^{(r)})$, $(q^{(lm)})$ form a set of mutually normal unit vectors, and $(u^{(l)})$, $(v^{(lm)})$ form another such set, and the ϕ_{lm} are a complete set for each value of l of real orthogonal functions of the variable g in the real interval (α_l, β_l).

From this we get to the analogue of Weierstrass's theorem mentioned above. It may be stated as follows:

If two independent members of the family of forms $(\rho A + \sigma B)(x, x)$ are definite, and one of them is also complete, we may write

$$A(x, x) = \sum_r \lambda_r (y^{(r)}, x)^2 + \sum_l \left[\sum_{m,n} \int_{al}^{\beta l} \lambda_l(g)\, \phi_{lm}(g)\, \phi_{ln}(g) dg \right.$$
$$\left. (y^{(lm)}, x)\,(y^{(ln)}, x) \right],$$
$$B(x, x) = \sum_r \mu_r (y^{(r)}, x)^2 + \sum_l \left[\sum_{m,n} \int_{al}^{\beta l} \mu_l(g)\, \phi_{lm}(g)\, \phi_{ln}(g) dg \right.$$
$$\left. (y^{(lm)}, x)\,(y^{(ln)}, x) \right],$$

where (1) the functions $\phi_{lm}(g)$, $(m = 1, 2, \ldots)$, form a complete set of orthogonal functions for the interval (a_l, β_l),

(2) the functions $\lambda_l(g)$, $\mu_l(g)$, and the numbers λ_r, μ_r are bounded,

(3) the vectors $(y^{(r)})$, $(y^{(lm)})$, $(r, l, m = 1, 2, \ldots)$, arranged in a simple sequence, are vectors of a complete matrix.

In the finite case the reduction to sums of squares is possible if *one* member of the family is definite and complete. For a finite number of variables, if $A(x, x) > O$, then, for sufficiently small values of λ, $(A + \lambda B)(x, x) > O$. In the infinite case this is not necessarily so, and we must insist that *two* members of the family should be definite.

Such a simultaneous expansion defines the *spectrum* of A with respect to B; it consists of a point spectrum, the set of points $K_r = \lambda_r/\mu_r$, and of a continuous spectrum, the set of values of the functions $\lambda_l(g)/\mu_l(g)$. Mr. Hyslop proves that the spectrum is uniquely defined independent of the particular expansions from which it is obtained.

In a concluding section the author applies his results to a dynamical system with an infinite number of degrees of freedom and in particular to the problem of the small transverse vibrations of a stretched string of variable density, disturbed in the vicinity of a fixed end, the other end being infinitely remote. This problem was first propounded, in 1897, by Wirtinger, who foresaw that, with certain distributions of density at least, a continuous spectrum must result.

The Allied Series of a Fourier Series.—Suppose that the function $f(t)$ is integrable in Lebesgue's sense and that its Fourier series is

$$\tfrac{1}{2}a_0 + \sum_1^\infty (a_n \cos nt + b_n \sin nt).$$

Then the series

$$\sum_1^\infty (b_n \cos nt - a_n \sin nt)$$

is called the *allied* series of the Fourier series; it is not necessarily itself a Fourier series. For example, $\sum_{2}^{\infty} \cos nx/\log n$ is a Fourier series, but $\sum_{2}^{\infty} \sin nx/\log n$, although convergent for all values of x, is not a Fourier series, since its sum function is not integrable in Lebesgue's sense in any interval which includes the origin. This example is due to Fatou (*Acta Math.*, **30** (1906), 335–400), who implicitly discussed one problem in the summability of the allied series. But the first explicit investigation of this question is due to Young (1911–12), who proved that the allied series is summable (C, 1) if the integral

$$g(x) = \frac{1}{2\pi}\int_0^{\pi}\{f(x+t) - f(x-t)\} \cot \tfrac{1}{2}t \, dt,$$

the formula for the sum of the allied series, exists, in Cauchy's sense, as a limit of the type $\lim\limits_{\epsilon \to 0} \int_{\epsilon}^{\pi}$, and

$$\int_0^{u} | f(x+t) - f(x-t) | \, dt = o(u).$$

This last condition is certainly satisfied for all values of x in which $|f(x) - q|$ is the derivative of its integral, whatever be q. This set is called the *Lebesgue set*; the complementary set has measure zero, so that the condition holds almost always. In the Lebesgue set the Fourier series is summable (C, δ) for every positive δ, *i.e.* the Fourier series is summable (C, δ) almost always. Is the same true for the allied series? Fatou showed (*loc. cit.*) that, if x is a point of continuity of $f(x)$, the integral $g(x)$ exists, as a Cauchy integral, if and only if the harmonic function

$$\Sigma (b_n \cos nx - a_n \sin nx) r^n$$

tends to a limit as $r \to 1$; *i.e.* if and only if the allied series is summable by Abel's limit. Plessner (*Mitt. Math. Seminar, Giessen*, **10** (1922), 1–36) showed that Fatou's result holds for all points of the Lebesgue set and for summability (C, 1). Hence if we can prove that $g(x)$ exists for almost all values of x we shall have proved that the allied series is summable (C, 1) for almost all values of x. This has been done by Plessner, but in an indirect way, depending upon the theory of analytic functions; direct proofs have so far only been given for functions of integrable square by Besikovitch (*Fundamenta Math.*, **4** (1923), 172–95) and for functions of which any power higher than the first is integrable by Riesz and Titchmarsh.

Using these results C. H. Hardy and J. E. Littlewood (*Proc. L.M.S.*, **24** (1925), 211–46) have succeeded in proving that the allied series is summable (C, δ) for every positive δ

and almost all values of x. To do this they prove that, in the Lebesgue set, the allied series is either summable by every Cesàro mean of positive order or summable by no Cesàro mean ; the main theorem then immediately follows by combination with Plessner's theorem.

They then go on to find the necessary and sufficient conditions for the summability of the series by the aggregate of Cesàro's means. Suppose that $\phi(t)$ is integrable in Lebesgue's sense in (ϵ, a) for every positive ϵ and that $\chi(\epsilon) = \int_\epsilon^a \phi(t)\,dt$. Then the integral $\int_0^a \phi(t)\,dt$ is said to exist in the Cesàro sense or to be summable (C), if $\chi(\epsilon)$ tends to a limit in the Cesàro sense when $\epsilon \to 0$, *i.e.* if

$$\frac{1}{\epsilon}\int_0^\epsilon \frac{d\epsilon_1}{\epsilon_1}\int_0^{\epsilon_1}\frac{d\epsilon_2}{\epsilon_2}\ \cdots\ \int_0^{\epsilon_{r-2}}\frac{d\epsilon_{r-1}}{\epsilon_{r-1}}\int_0^{\epsilon_{r-1}}\chi(\epsilon_r)\,d\epsilon_r$$

tends to a limit for some value of r. This being so, it is proved in the paper referred to that the necessary and sufficient condition that the allied series should be summable (C) is that the integral $g(x)$ should be summable (C).

A final section discusses the integral

$$\int_0^a \frac{f(x+t) - f(x)}{t}\,dt.$$

Its behaviour differs strikingly from that of the integral

$$\int^a \frac{f(x+t) - f(x-t)}{t}\,dt$$

which dominates the discussion of the allied series. The latter converges, for almost all x, for every integrable f, but the former may diverge for almost all x even when f is continuous. This former integral is connected with the series $\Sigma(s_n - s)/n$, where s_n is the sum of the first $(n + 1)$ terms of the Fourier series of $f(x)$, and s is a number independent of n, very much as the latter is connected with the allied series. Theorems illustrating this connection are given and a sufficient condition that the integral should converge almost everywhere and represent a function of integrable square is obtained, viz. that $\Sigma(a_n^2 + b_n^2)(\log n)^2$ should be convergent.

The Riemann Zeta-function.—J. E. Littlewood (*Proc. L.M.S.*, 24, 1925, 175–201) obtains new results, depending for the most part upon the Riemann hypothesis as to the zeros of $\zeta(s)$. To summarise them we must recapitulate the preliminary ideas. For $\sigma > \frac{1}{2}$ let $\nu(\sigma)$ be the least value of ξ such that

$$f(s) = f(\sigma + it) = \log\ \zeta(s) = O\ \{(\log t)^{\xi+\epsilon}\}$$

as $t \to \infty$. Then it is known, from earlier work of Mr. Littlewood himself and of H. Bohr and E. Landau, that

$$\nu(\sigma) = O \ (\sigma \geq 1),$$
$$\left.\begin{array}{l}\nu(\sigma) \leq 2(1-\sigma)\\ \nu(\sigma) \geq b(1-\sigma)\end{array}\right\}(\tfrac{1}{2} < \sigma \leq 1),$$

where b is a positive constant; and that $\nu(\sigma)$ is a convex, continuous, and decreasing function of σ in the interval $\frac{1}{2} < \sigma \leq 1$. One of the main results of the paper is to show that we may take $b = 1$ in the last inequality, and so the author does not assume this inequality but begins with the much less deep result for the lower bound of $\nu(\sigma)$ that $\nu(\sigma) \geq O$.

In a similar way we may call the least ξ corresponding in the same way to any other function $\phi(s)$ in place of $f(s)$ the ν-function of ϕ. It is shown that the differential coefficients and the repeated integrals (with $+\infty$ as the lower limit) of $f(s)$ have the same ν-function in $\sigma > \frac{1}{2}$ as $f(s)$ itself and that the ν-functions of the real and imaginary parts of any derivative or integral of $f(s)$ are equal to $\nu(\sigma)$ for $\sigma > \frac{1}{2}$. We define, formally, $\nu(\frac{1}{2}) = \lim\limits_{\epsilon \to 0} \nu(\frac{1}{2} + \epsilon)$, and then put $\nu(\sigma) = 2(1-\sigma)\beta(\sigma)$.

It follows that $\beta(\sigma)$ is a decreasing function (in the wide sense) in $\frac{1}{2} \leq \sigma < 1$. Defining $\beta(1) = \lim\limits_{\sigma \to 1-0} \beta(\sigma)$ and writing $\beta = \beta(\frac{1}{2})$ we have

$$\beta(1) \leq \beta(\sigma) \leq \beta \leq 1 \quad (\tfrac{1}{2} \leq \sigma \leq 1).$$

It is further known that the imaginary part of $f(s)$ tends to a limit as $\sigma \to \frac{1}{2}$, subject to a convention when s is a zero of $\zeta(s)$; this limit we call $\pi S(t)$. Moreover, constants $a_1, a_2 \ldots$ exist such that

$$S_0(T) = S(T), \ S_{n+1}(T) = \int_0^T S_n(t)\,dt + a_{n+1},$$

and

$$S_n(T) = O\left(\frac{\log T}{(\log \log T)^{n+1}}\right).$$

Finally, we define a set of indices $\alpha = \alpha_0, \alpha_1, \alpha_2 \ldots$ by the relations

$$S_n(T) = O\{(\log T)^{\alpha_n + \epsilon}\},$$
$$S_n(T) \neq O\{(\log T)^k\}, \ (k < \alpha_n).$$

A large part of the paper deals with the relations between the α's and β's. It is known from the work of Bohr and Landau that $\alpha > o$, but no use is made of this result. Moreover, it must be remarked that, although the imaginary part of $f(s)$ has $\beta(\sigma)$ for β-function when $\sigma > \frac{1}{2}$, it by no means follows that

$\alpha = \beta$. Mr. Littlewood says: "It is an attractive and not unreasonable conjecture that $\alpha = 1$, $\beta = \frac{1}{2}$." He proves on the one hand that $\alpha_n \geqslant \beta$ and, on the other, that $\beta \geqslant \beta(1) \geqslant \frac{1}{2}$; the latter theorem depending upon certain approximate formulæ for $\zeta^1(s) / \zeta(s)$, combined with an appeal to theorems of Diophantine approximation. In a further section the behaviour of $\zeta(s)$ on the line $\sigma = 1$ is discussed; it is shown that $\overline{\lim} \{|\log \zeta(1 + it)| / \log \log t\}$ lies between two positive bounds which differ by a factor $2\beta(1) \leq 2$; the exact value is thus obtained if it is true that $\beta(1) = \frac{1}{2}$. Finally the mean value of $|(S_n(T)|$ is studied. The earlier results show that the "order" of $S_n(T)$ as a function of $\log T$ is at least $\frac{1}{2}$; it is now proved that

$$\frac{1}{T}\int_0^T |S_n(t)|\, dt = \begin{cases} O(1) & (n > 0) \\ O(\log \log T) & (n = 0), \end{cases}$$

so that the *average* order is zero.

METEOROLOGY.

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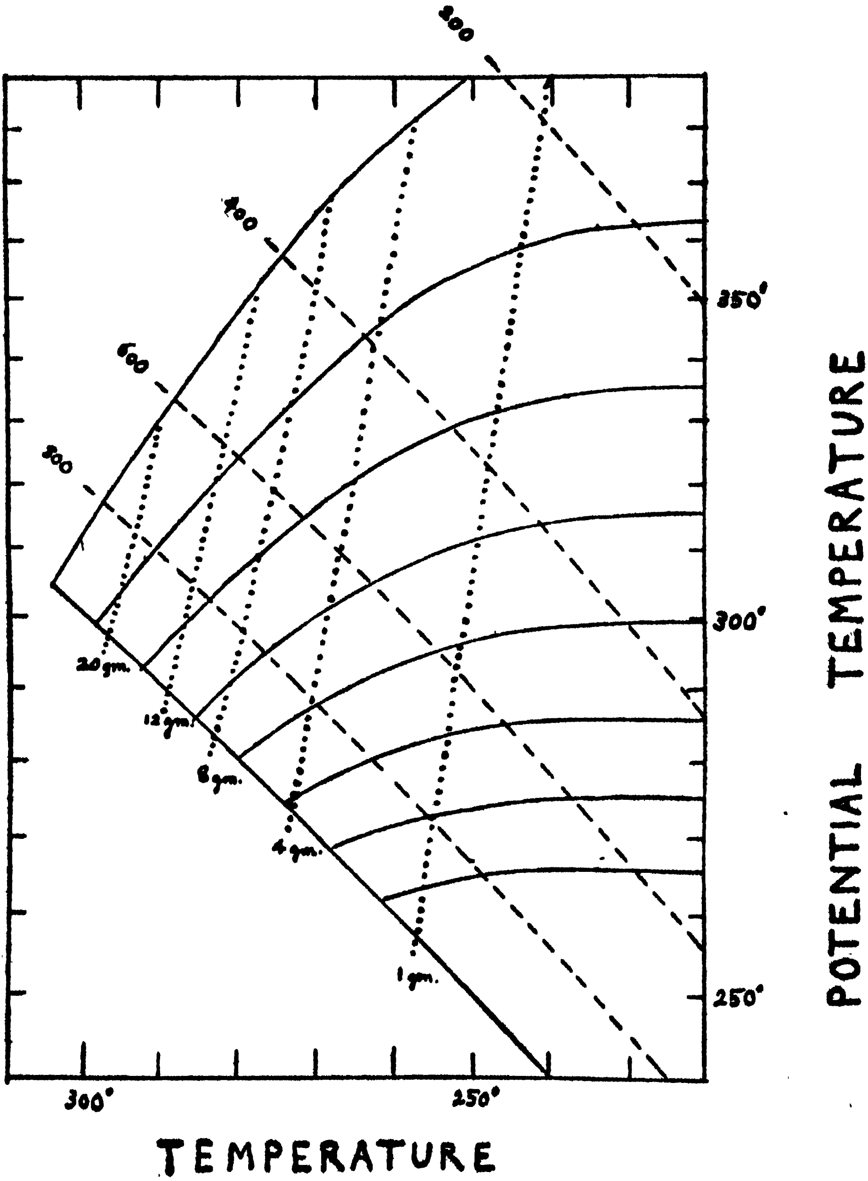
In the *Quarterly Journal of the Royal Meteorological Society*, vol. 51, no. 215, July 1925, a paper appears entitled "The Energy of Saturated Air in a Natural Environment," by Sir Napier Shaw and H. Fahmy. Sir Napier Shaw has for many years advocated the application of thermodynamical principles to the solution of various meteorological problems. That so little has been done in this direction is no doubt due to the fact that very few meteorologists have ever had occasion to acquire more than a very superficial knowledge of this difficult branch of physics. It has long been known that the normal fall of temperature with height in the atmosphere is, at least over the land, less than the so-called "dry adiabatic lapse rate" which would be established if the atmosphere were stirred up in such a way that the air in each horizontal layer were thoroughly scattered in a vertical direction. In a thoroughly stirred-up atmosphere of this kind the temperature would fall 9·9° C. for each kilometre of height, and a sample of dry air would rise indefinitely were it warmed by the smallest amount, for it would at all levels find itself a trifle warmer and therefore less dense than the surrounding air. In "natural environments," on the other hand, the "lapse-rate" being normally less than the "dry adiabatic," a sample of air if forced upwards becomes increasingly colder than its surroundings, and its greater relative density opposes the upward movement.

With a sample of saturated air the situation is quite different. As the temperature of the sample falls, some of the water vapour condenses, and the latent heat liberated



retards the cooling. The question as to whether it can rise is no longer a simple one.

Herz was the first person to attempt a solution of this problem of the ascent of moist air. Many years ago he calculated the changes of pressure and temperature for ascending saturated air, starting from various initial temperatures, and set out the results in a diagram in which the temperature was in each case plotted against the pressure, while lines showing the position on the diagram of various heights were added. Herz in his mathematical calculations considered the behaviour of a kilogram of a mixture of dry air and water vapour, but Neuhoff has more recently solved the same problem by considering the behaviour of a mixture of 1 kilogram of dry air with x grams of water vapour. In the present paper Neuhoff's equations are used. It is important to notice that the curves obtained are adiabatic only in the sense that no external heat is supposed to be applied; actually the entropy of the dry air increases, for the latent heat from the condensing water vapour becomes "realised entropy" in the dry air. The water vapour is neglected[1] except in so far as it is a source of this "realised entropy."

Shaw and Fahmy found after some experimenting that the form of diagram shown in the accompanying figure is the most satisfactory for dealing with the ascent of moist air. The temperature scale is linear, the potential temperature scale logarithmic. On this diagram a dry adiabatic lapse-rate is represented by a horizontal line. The solid curves are the "adiabatics" for saturated air of various temperatures. The dotted lines show various values of x in grams, and the pecked lines represent pressure.

It is an extremely simple matter to determine with the aid of this diagram whether a sample of saturated air is unstable, and if so, to what point it must rise before it finds itself in equilibrium with its environment, provided the sample does not mingle with the surrounding air. It is first necessary to draw a graph of the environment. From the various pairs of observations of temperature and pressure obtained by a balloon sounding, the potential temperatures can be calculated, or else, if great accuracy is not required, the observations can be plotted at once, making use of the sloping lines of pressure. If now the point representing the sample of saturated air be marked, then the sample will be unstable if this point lies on the warm side of the graph of environment, and it will evidently rise along the saturation adiabatic until that line cuts the graph of environment.

In a similar way the diagram can be used to find the position of equilibrium of a sample of air which is not initially saturated but is warm enough to rise, even in an environment having less than the dry adiabatic lapse-rate, to such a height that saturation is reached. The procedure in this case is to calculate the dew-point in the ordinary way, and then to follow the dry adiabatic line appropriate to the initial temperature and pressure of the sample (this line is of course horizontal) towards the right until either the moisture-content line corresponding with the dew-point or else the curve of environment is encountered. If the moisture line is the first to be encountered, this means that the rising air is saturated while still warmer than the environment, and it can now continue to rise, following the moist adiabatic line which passes through the point of intersection, until the moist adiabatic cuts the curve of environment. If, on the other hand, the dry adiabatic line meets the curve of environment first, then this means that the sample of air has attained to the temperature of the environment while still unsaturated, and can rise no further.

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[1] The water drops are assumed to fall out of the sample, therefore the "adiabatics" are irreversible.

In any of these cases of ascending moist air the moisture-content lines enable the amount of water vapour that has condensed to be determined by simple subtraction.

With the co-ordinates here made use of, since the log of the potential temperature is proportional to the realised entropy of the kilogram of dry air, we have the equivalent of the indicator diagram, *i.e.* any given area represents so much energy. In the case of an ascending mass of air, a certain area is enclosed between the moist adiabatic and the curve of environment, and this presumably is a measure of the surplus energy possessed by the air.

The paper contains a number of calculations of the height to which air having certain specifications can rise, using data obtained on various English *ballon-sonde* ascents for defining the environment, and of the moisture precipitated, and of the surplus energy available. It closes with some calculations of the kinetic energy of a certain ideal type of cyclone.

At the meeting of the British Association at Southampton, Dr. G. C. Simpson, in his presidential address to the Mathematical and Physical Section, summarised in a very lucid way some of the new ideas about the atmosphere that have been evolved during the past twenty-five years. This address is published in *Nature* (vol. 116, no. 2914, Sept. 5, 1925, pp. 361–5). Most of the points discussed have been dealt with in recent numbers of SCIENCE PROGRESS, but some of Dr. Simpson's remarks have some bearing upon the problems dealt with in the paper of which an abstract has just been given. Little has been said by the authors of that paper about the *descent* of air. Dr. Simpson points out that we have clear evidence of the ascent of limited masses of air, rising balloon-like through the surrounding air, *e.g.* the development of the ordinary cumulus cloud, or of the thundercloud, and Shaw and Fahmy have just indicated the conditions that must be satisfied to make such ascent possible; but if air goes up air must come down. Just as the normal lapse-rate of the atmosphere opposes the ascent of dry air, so it opposes the descent of either dry or saturated air, and there is no mechanism analogous to condensation which can quickly abstract heat and allow of continued descent on a scale similar to that of the two examples of ascent just referred to. The only way left appears to be by gradual subsidence, and as the extent of the vertical movement cannot be great, the requisite transference of air is presumably arrived at by subsidence over large areas. This subject was dealt with mathematically by Margules about twenty years ago. He showed that the kinetic energy developed in the cyclones of temperate latitudes is adequately explained if we suppose that suitably large masses of cold air subside and creep underneath corresponding masses of relatively warm air, which are lifted in the process. The result is a lowering of the centre of gravity of the whole mass and a reduction of the potential energy with a corresponding development of kinetic energy in the form of wind.

An abstract of a lecture delivered by Prof. V. Bjerknes, entitled "Polar Front Meteorology," appears in the *Quarterly Journal of the Royal Meteorological Society*, vol. 51, no. 215, July 1925, pp. 261–5. In this lecture the theoretical grounds for the recently developed Norwegian methods of forecasting were set out. Prof. Bjerknes pointed out that in the classical treatises on hydrodynamics only "barotropic" fluids are considered, *i.e.* fluids in which the density is completely controlled by the pressure, so that surfaces of equal density are always isobaric surfaces. The barotropic condition does not permit the formation of vortices, although such would continue were it possible to produce them, nor does it permit the formation of movements maintained by thermodynamical means. These and other limitations make the classical theorems inapplicable to the movements of the earth's atmosphere. By consideration of "baroclinic" fluids, *i.e.* fluids in which surfaces of equal density are inclined to and cut isobaric surfaces, the lecturer was led to the general theory of hydrodynamical action at a distance and to general theorems regarding atmospheric circulation. These theorems, it is claimed, can be applied to the large circulatory movements of the atmosphere which are undoubtedly produced and maintained thermodynamically. By the assumption of the existence of surfaces of discontinuity in the atmosphere, the latter can be regarded as made up of nearly barotropic layers separated from one another by strongly baroclinic layers, or, in extreme cases, by surfaces of discontinuity. Making this assumption, the lecturer considered the effect of a small disturbance upon two barotropic layers lying horizontally one upon the other, and showed how waves would be set up which would travel along the surface of separation. He then considered the effect of the earth's rotation on the wave motion between winds which are in contact over a horizontal surface, and which possess different velocities, taking the upper layer to be a west wind and the lower layer an east wind. The rotation would cause each to tend to move to the right, and the surface of separation would become inclined according to Margule's formula, with a slope of the order of 1 in 100, cutting the earth along a parallel of latitude, the westerly current overlying the easterly north of this latitude. The result is the " polar front." In the surface of separation the wave motion will appear as an undulatory movement of the polar front together with vortices travelling from west to east. (For a more detailed exposition of the arguments briefly outlined above, see *Le Journal de Physique et le Radium*, vol. 5, no. 11, 1924, p. 321.)

In *Comptes Rendus*, tome 181, no. 9, Aug. 31, 1925, pp. 323–6, there is a short paper by Faucher and Rougetet entitled " Contribution a l'étude du mistral. L'accélération." The authors studied the velocity of the northerly or north-westerly winds of Provence, known as the mistral, along a section of the Rhone valley about seventy kilometres in length, in the neighbourhood of Saint-Vallier and Montélimar. A number of observers were supplied with standardised hand anemometers, and observations were made, apparently by day only and in the summer, along a chain of observing stations at certain fixed hours during a spell of mistral, during part of 1924 and 1925. They found that the velocity of the mistral almost always exceeded the theoretical velocity corresponding with the pressure gradient at the time, and that there was continual acceleration along the path of the wind. Two typical examples are given : one with high pressure over Central France, and low pressure over the Gulf of Genoa and the Tyrrhenian Sea (the classical situation for the formation of the mistral), and a fairly strong pressure gradient ; the other with low pressure and very little gradient. The stretch of the Rhone valley under consideration is made up of a series of low-lying plains or basins, separated by passes, and it was principally over these plains that acceleration took place. The authors contend that it is the orographical nature of these plains which causes the acceleration, the configuration being favourable for rapid evaporation over the central regions and strong solar heating on the slopes of the hills, leading to slight reductions of pressure in each of the plains.

In *The Monthly Weather Review*, vol. 53, no. 7, July 1925, two papers appear which deal with the question as to whether it is legitimate to assume that day to day variations in the radiation emitted by the sun occur, on the evidence supplied by the Astrophysical Observatory of the Smithsonian Institution. The first of these, by C. F. Marvin, contains a very thorough examination of the most recently published determinations of the "solar constant" made at Calama (Chile) between July 1918 and July 1919, and a comparative study of certain sets of determinations at other places, using modern mathematical statistical methods. The desirability of some critical study of this kind has been felt by meteorologists ever since claims have been made by certain American writers of a close connection between changes in the weather and variations in the "solar constant." In a recent essay-review[1] of Clayton's "World Weather" this need was emphasised, in view of the fact that weather changes of a most precise kind were deduced by that writer from alleged variations of the "solar constant," although the magnitude of such variations were shown by him to be dependent to a large degree upon where the measurements were made. Marvin's paper brings out very clearly the extreme difficulty of allowing for the effects of scattering and absorption of the different wave-lengths received on the earth's surface from the sun, and he finds evidence in his statistical results of the inadequacy of the methods of extrapolation that have been used for determining the radiation outside the atmosphere, based on the Bouguer-Langley exponential law for monochromatic radiation, *viz.*:

$$i = Ia^m,$$

where i is the intensity after passing through a mass "m" of air, and I is the initial radiation for the wave-length in question.

The evidence shows that when the "solar constant" appears to depart from its mean value by certain amounts at two different stations, and these departures have the same sign, part at least of this agreement is due to inadequate correction of atmospheric effects occurring at both stations simultaneously. His final conclusion is that any genuine variability of the sun's total radiation must be very small, and that it is not yet possible to say what proportion of the standard deviation of the "solar constant" might be due to such variability, and what proportion to errors of correction for atmospheric absorption, etc. At the same time he throws out valuable suggestions as to how the two causes of variation can be segregated statistically, and as to the best way of conducting the observational work with this end in view.

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[1] Science Progress, vol. xix, p. 679.

The second of the two papers referred to above is by H. H. Kimball. He also considers the errors in determinations of the "solar constant," both in the fundamental readings and in the corrections for loss in transmission through the atmosphere, and examines the correlation between simultaneous determinations at Montezuma (Chile) and Harqua Hala (Arizona). His conclusion is that only an insignificant part of the day to day variations can be attributed to solar variability, and that the existence of even such slight variability is at the present time hypothetical.

PHYSICS. By L. F. Bates, B.Sc., Ph.D., F.Inst.P., University College, London.

Collisions of the Second Kind.—From the experiments of a large number of workers on the ionisation and radiation produced by the impact of electrons with atoms, it clearly follows that a collision between an atomic system and a free electron in certain cases may result in a transition of the atomic system from one stationary state to another without the emission of radiation, whilst the free electron loses an amount of kinetic energy such that the principle of the conservation of energy holds for the collision. In a classic paper, Klein and Rosseland (*Zeit. für Phys.*, **4**, p. 46, 1921) considered the effect which such collisions would have on the temperature equilibrium of a mixture of atomic systems and free electrons. In the absence of electrons, of course, there would be a statistical equilibrium between the atoms and the temperature radiation, when the energy distribution of the latter corresponded to that required by Planck's radiation hypothesis. It would appear *a priori* that the statistical equilibrium distribution of the velocities of the free electrons, and also the statistical equilibrium distribution of the atomic systems in their various stationary states, corresponding to the transitions produced by the temperature radiation, would be disturbed. For, some atoms would be raised to higher stationary states owing to collisions with free electrons, whilst the impacting electrons would simultaneously lose kinetic energy. Since some of these excited atoms would immediately radiate, it follows that there would be a general decrease in the energy of free electrons and a general increase in the energy of the atoms and of the radiation; *i.e.* the temperature of the radiation would increase whilst the temperature of the electrons would decrease. This would obviously constitute a breach of the second law of thermodynamics. It therefore follows that such collisions must be compensated, and, moreover, this compensation must be completely effected by the electrons themselves, as soon as the velocities of the latter are distributed in accordance with the temperature equilibrium. In this manner Klein and Rosseland came to the conclusion that, as a necessary consequence of the experiments on ionisation and radiation produced by electron impact, collisions must occur between atomic systems and free electrons, in which an impacted atom may pass from a higher to a lower stationary state without the emission of radiation, whilst the free electron, as a result of the collision, obtains an increase in kinetic energy exactly equal to the energy lost by the atom. Such collisions Klein and Rosseland termed collisions of the second kind, in order to distinguish them from the previously studied impacts, which were termed collisions of the first kind. Klein and Rosseland further obtained a relation between the probabilities of the occurrence of collisions of the first and of the second kind, which showed that the probability of collisions of the second kind is very great when the velocities of the colliding electrons are small, and this is to be expected, because the probability of a free electron coming under the influence of an atom will naturally be very large when the velocity of the electron with respect to the atom is small. In fact, the probability of increase in kinetic energy by collisions of the second kind in the case of slow electrons, must be the same as that for loss of energy by collisions of the first kind in the case of the faster electrons, in order that thermodynamic equilibrium may be possible in a mixture of atoms and electrons in which we assume the Maxwell distribution of velocities to hold for both.

Now Franck (*Zeit. für Phys.*, **9**, p. 259, 1922) showed that precisely the same argument must apply to the collisions of atoms and molecules, for it is well known that radiation may be produced by atomic and molecular impacts. Naturally, researches similar to those which give information about the number of quantum transitions occurring with electron impacts of the first kind can scarcely be carried out with atomic and molecular impacts, but, as Franck pointed out, it is easy to determine the number of collisions of the second kind and thereby to obtain indirectly the number of collisions of the first kind. To do this it is only necessary to determine the percentage of excited atoms or molecules which undergo radiationless transition from the excited state to the normal state by virtue of collisions of the second kind with non-excited atoms. In this connection Franck referred to the results of experiments on the reduction in intensity and the modification of the fluorescent spectra of gases, like iodine vapour, which occur when traces of other gases are introduced—these experiments forming very convincing examples of radiationless collisions. Thus the fluorescent spectrum of iodine vapour at low pressures is not only reduced in intensity by the addition of traces of another gas, but the nature of the spectrum itself is changed. When pure iodine vapour is illuminated by monochromatic light, only the resonance line spectrum is emitted, but on the addition of another gas, bands appear and the region of maximum intensity is displaced towards the red. The appearance of these bands, denoting transitions with the emission of smaller quanta of energy, shows that an excited molecule, by losing its rotation and vibration quanta to increase the kinetic energy of an atom or molecule of the added gas, may pass directly to a lower quantum state without the emission of radiation, and may then radiate light of greater wave-length than would otherwise have been emitted. Now, in the above case, the large number of possible quantum transitions make it very difficult to interpret the experiments quantitatively, and Franck suggested that similar experiments should be made with monatomic gases, and Cario (*Zeit. für Phys.*, **10**, p. 185, 1922) therefore made measurements on the decrease of the resonance fluorescence of the mercury line 2536·7 Å which accompanies the addition of another gas. The first experiments in this connection were made by R. W. Wood (*Phys. Zeit.*, **13**, p. 353, 1912), who exposed mercury vapour in a quartz vessel to light of wave-length 2536·7 Å, and observed the decrease of resonance radiation when small quantities of air were introduced into the vessel. From Wood's results, Cario first calculated the diameter of an excited mercury atom, on the assumption that each collision of an excited mercury atom with a molecule of air, *i.e.* of nitrogen or oxygen, was a collision of the second kind. The number of collisions calculated on the basis of the kinetic theory of gases is

$$Z = \sigma^2 \cdot p \cdot 2666 \cdot 6 \sqrt{\frac{2\pi L}{k\theta}} \sqrt{\frac{m_1 + m}{m \cdot m_1}}$$

where σ is the sum of the radii of the excited mercury atom and a molecule of nitrogen or of oxygen, p is the pressure of the air added to the mercury vapour, in mm. of mercury, L the number of molecules in one gm. molecule, k the Boltzmann constant, θ the absolute temperature, m the atomic weight of mercury, and m_1 the molecular weight of nitrogen or of oxygen. Since we may consider that the number of excited atoms decreases exponentially with time, and if we suppose that at a time $t = 0$, q_0 atoms are in the excited state and that no further excitation occurs, then, after a time t there will exist $q_t = q_0 \cdot e^{-t/\tau}$ excited atoms, where τ is of the order of 10^{-8} sec. Further, if in a time $T = 1/Z$, which is the average time between two interatomic collisions, n atoms are excited, then the number of atoms which radiate in the interval T will on the average be equal to

$$x = \int_0^{\mathrm{T}} \frac{n\,dt}{\mathrm{T}} \left(1 - e^{\frac{-\mathrm{T}-t}{\tau}}\right) = n\left[1 - \frac{\tau}{\mathrm{T}}\left(1 - e^{\mathrm{T}/\tau}\right)\right]$$

Now the degree of intensity of the resonance radiation may be measured by the ratio of the number of atoms which radiate to the number which are excited in the same interval of time, *i.e.* by

$$\frac{x}{n} = 1 - \frac{\tau}{\mathrm{T}}\left(1 - e^{-\mathrm{T}/\tau}\right) = 1 - \tau Z\left(1 - e^{-1/\tau Z}\right).$$

The nature of the decrease thus calculated by Cario agrees well with that found experimentally by Wood, if the value $5{\cdot}98 \times 10^{-8}$ cm. is substituted for σ. This means that the diameter of the excited mercury atom is $9{\cdot}1 \times 10^{-8}$ cm. Since the diameter of the excited atom must be greater than the diameter of the normal atom, this value is of the right order of magnitude, and the assumption that each collision of an excited atom with a molecule of air is a collision of the second kind appears justified. Cario's own experiments on the decrease in fluorescence caused by adding traces of the rare gases to mercury vapour show definitely that collisions of the second kind, and not chemical action, are responsible for the observed decrease. The mercury vapour in his experiments was caused to fluoresce by suitable electron impact, and the curves obtained show the same kind of decrease in intensity on the addition of larger amounts of argon and helium-neon mixture, although the actual decreases are not equal for equal pressures of argon and of helium-neon mixture added. These curves cannot be evaluated in the same way as Wood's curve, since they deviate considerably from the formula obtained above and which Wood's curve satisfies, but if these experimental curves are compared with theoretical curves obtained by assuming the atomic diameters of argon, neon, and helium to be $2{\cdot}5 \times 10^{-8}$, $2{\cdot}1 \times 10^{-8}$, and $1{\cdot}7 \times 10^{-8}$ cm. respectively, then it can be stated with certainty, that with the addition of a helium–neon mixture (23 helium + 77 neon) the diameter of the excited mercury atom must be considered to be at least 3 times greater, and with the addition of argon, to be at least $5{\cdot}5$ times greater, in order to explain the observed results. It is suggested that the reason for this difference in the values of the diameter of the excited mercury atom is that every collision between an excited atom and a light atom is not a collision of the second kind, *i.e.* that the yield of collisions of the second kind is less than 100 per cent. Incidentally, the experiments of Stuart (*Zeit. für Phys.*, **32**, p. 262, 1925) show that a most varied efficiency in producing reduction of fluorescence is possessed by different gases. However, the net result of these experiments is that every collision of an excited mercury atom with a neutral atom of a heavy gas may be regarded as a collision of the second kind, for the order of magnitude of the excited mercury atom found from these experiments agrees with that found by the independent experiments of Füchtbauer and Schnell (*Phys. Zeit.*, **14**, p. 1164, 1913) and of Füchtbauer and Joos (*Phys. Zeit.*, **23**, p. 73, 1922).

Turner (*Phys. Rev.*, **23**, p. 464, 1924) has derived an equation, similar to that of Cario, for the relation between the rate of dissociation of hydrogen molecules by excited mercury atoms and the pressure of hydrogen. His theory leads to an expression for $\sigma^2\tau$, where σ is the distance between the centres of an excited mercury atom and of a hydrogen molecule during a collision, and τ is the average duration of the excited state. The value of $\sigma^2\tau$ is found from Franck and Cario's experimental results to be equal to $7{\cdot}22 \times 10^{-22}$. Assuming σ to be of the order of magnitude of atomic diameters, he finds τ to be 10^{-7} sec., and his equation seems to fit these experimental results better than Cario's equation. The fact that the data agree with such a simple theory indicates that collisions of excited mercury atoms with normal mercury atoms have a negligible effect. Turner also applies his theory to R. W. Wood's results, extending his theory to cover the possibility of successive impacts of the excited mercury atom. This extended theory is found to agree qualitatively with Wood's results at higher pressures, indicating an increased rate of production of excited mercury atoms for the same illumination, and a smaller value of τ with air than with hydrogen.

Franck (*loc. cit.*) also pointed out that the existence of collisions of the second kind would explain the emission of certain lines in fluorescent spectra which would not be expected in the ordinary course of events. Thus, Wood observed that when mercury vapour is illuminated with light of wave-length 1849 Å, the vapour emits the line 2536·7 Å, $1S - 2p_2$, as well as the 1849 Å line, $1S - 2P$. Since the principle of selection forbids a direct quantum transition, or even a transition by stages, from the $2P$ to the $2p_2$ state, the above result might be explained on the assumption that an atom in the $2P$ state absorbed infra red radiation of wave-length 10140 Å, and then proceeded to the $2p_2$ state with the emission of the line 4078 Å. As the 4078 Å line is not observed, this explanation must be regarded as improbable. An explanation based on the formation and destruction of Hg_2 molecules is also unsatisfactory.

However, if excited atoms in the 2P state collide with free electrons or atoms they may fall to the $2p_3$ state without radiating, and thence reach the 1·5S state by the emission of the 2536·7 Å line. The selection principle in this case would not be violated, as it could not be applied in view of the intense field between the colliding systems. Now the above experiments deal only with electron transitions in the same kind of atom. Cario (*loc. cit.*) therefore made experiments with a mixture of atoms, in which the energy of a quantum transition in one kind of atom was absorbed by an atom of another element by means of a collision of the second kind. He first used a mixture of mercury and thallium vapours. In one side of a quartz vessel, maintained at 100° C., was placed some mercury, and in the other side, heated to about 800° C., was placed some thallium. These temperatures gave vapour pressures of 0·25 mm. for mercury and about 2 mm. for thallium respectively. The mixture of vapours was illuminated by light of wave-length 2536·7 Å from a cooled mercury arc, and the fluorescent light from the mixture was photographed by means of a quartz spectrograph. The photographs showed, in addition to the strong resonance line 2536·7 Å and other fainter mercury lines due to scattering, six lines due to thallium. These lines were emitted owing to collisions of normal thallium atoms with excited mercury atoms, the latter communicating energy to the thallium atoms of amount sufficient to raise them to states which do not differ from the normal state of the thallium atom by more than the quantum of energy corresponding to the 2536·7 Å line. Under these circumstances the emission of eight thallium lines would be expected, but two of these would be absorbed by the quartz. The six lines actually observed obeyed the selection principle and the intensity rule. Cario also made similar experiments with mixtures of mercury and silver vapours. In this case we should only expect to observe the $1S - 2p_1$ and the $1S - 2p_2$ lines of silver, and precisely these two lines were recorded. Many control experiments showed that the results were due to collisions of the second kind as described.

Suppose we next consider a mixture of gases consisting of two components, A and B, whose atomic weights are m and m_1. Let the gas A possess a line of frequency ν as the lowest frequency line of its absorption series, and let the corresponding line of the gas B have a frequency ν_1, where $\nu > \nu_1$. Now if we illuminate the mixture under suitable circumstances (*vide* Cario and Franck, *Zeit. für Phys.*, **17**, p. 202, 1923) with light of frequency ν, then ν and ν_1 should appear in the fluorescent radiation. Under these circumstances, in each exchange of energy between an excited A atom and a B atom, an amount of energy equal to $h\ (\nu - \nu_1)$ must be distributed as kinetic energy between the colliding atoms A and B. If the temperature of the mixture is so low that the thermal energy is small with respect to $h\nu$, then the atom B will receive, in addition to the energy required to excite it, an amount of kinetic energy equal to $\frac{1}{2} m_1 v^2 = h\ (\nu - \nu_1) \cdot \frac{1}{1 + {}^{m_1}/_{m}}$. The excited B atom should then radiate light of frequency $\nu_2 = \nu_1\ (1 + \frac{v_1}{c} \cos \phi)$, owing to the Doppler effect, and this light would not be absorbed by the other B atoms, which move far less quickly. On the other hand, if we illuminate the same mixture with light of frequency ν_1, then an emission of frequency ν can only result when the temperature of the mixture is so high that the extra energy necessary for the excitation of A, *i.e.* $h\ (\nu - \nu_1)$, may be obtained from the thermal energy during the collisions of an A atom with an excited B atom. These two effects were considered by Cario and Franck (*loc. cit.*), who succeeded, by using mixtures of mercury and thallium vapours and of mercury and cadmium vapours, in proving the second effect to exist ; the first effect they also showed to exist by experiments on the absorption of fluorescent radiation but sodium vapour.

Kopfermann (*Zeit. für Phys.*, **21**, p. 316, 1924) used the method of Cario and Franck to obtain information about the spectra of lead and bismuth, and he obtained photographs which showed that the results for lead agreed with the series formation given by Grotian (*Zeit. für Phys.*, **18**, p. 169, 1923) and by Thorsen (*Naturwiss.*, **11**, p. 78, 1923), and from the results for bismuth he was able to obtain further information of certain regularities in its spectrum.

The effect of collisions of the second kind in photochemical processes was initially raised by Franck (*loc. cit.*), and he cites the case of the sensitisation of a photographic plate. For the occurrence of a photochemical reaction two conditions are necessary : firstly, the incident radiation must be absorbed, and secondly, Einstein's law of photochemical reaction must be obeyed. Now, with a photographic plate coated with a silver halide and illuminated with red light the first condition is not satisfied, and the plate is not sensitive to this light. However, if the silver halide is stained with a dye which absorbs red light, then the plate becomes sensitive to light which in general belongs to the group of wave-lengths covered by the absorption band of the dye. This is to be expected, if we consider that the dye absorbs the energy of the red light through quantum transitions, and then by collisions of the second kind imparts it as kinetic energy to the silver halide, so that the latter becomes partially dissociated and behaves as if it were directly affected by red light. Incidentally, Franck further suggested that at very low temperatures where such a transference of energy would presumably be impossible, the absorbed radiation should be re-emitted as fluorescent radiation, and the intense fluorescence of solids at low temperatures, described by Goldstein, might thus be accounted for. It has long been known (Weigert, *Ann. der Phys.*, **24**, p. 243, 1907) that ozone, to which a little chlorine is added, is decomposed on exposure to light. Similarly, hydrogen is photochemically dissociated when it is illuminated with light of wave-length less than 3200 Å, provided that there is present a trace of another gas which absorbs this light, although from thermal data it would be expected that light of wave-length less than 1300 Å would be required to dissociate pure hydrogen. Cario and Franck (*Zeit. für Phys.*, **11**, p. 161, 1922) showed that mercury atoms excited by absorption of the 2536·7 Å line were able to dissociate hydrogen by collisions of the second kind. They illuminated a mixture of hydrogen and mercury vapour in a quartz tube which also contained copper or tungsten oxide. The water formed by the reduction of the oxide was removed by liquid air, and the consequent pressure decrease was measured by a Macleod gauge. Wolfram trioxide was also used and showed similar reduction effects, although Langmuir showed that this substance is only reduced by pure hydrogen at a temperature above red heat. More recently Dickinson (*Proc. Nat. Acad. Science*, **10**, p. 409, 1924) has shown that similar experiments may be carried out with oxygen gas instead of a metallic oxide, and that the reaction may take place at room temperatures. Duffendack and Compton (*Phys. Rev.*, **23**, p. 584, 1924) have drawn attention to the fact that the dissociation of molecules by the action of excited atoms should occur in low voltage arcs under suitable conditions. If, for example, a low voltage arc were maintained in mercury vapour in the presence of hydrogen, then we should expect a rapid disappearance (or " clean-up ") of the hydrogen, because for the maintenance of the arc a large concentration of excited atoms would be necessary, and this, of course, would be the condition for the rapid dissociation of the hydrogen present. The dissociated hydrogen disappears by secondary chemical action. They therefore made experiments to compare the importance of this mode of dissociation with that due to a hot filament alone or by direct electron impacts with gas molecules. The general conclusion drawn from these experiments was that the rate of disappearance of hydrogen was about ten times as great in a 5·3 volt mercury arc, and about three times as great in a 10·4 volt mercury arc, as in a pure hydrogen arc up to 65 volts, the highest used. Somewhat similar results, though much less pronounced, were obtained in the case of the dissociation of nitrogen in a mercury arc. At the recent meeting of the Faraday Society at Oxford (*Trans. Farad. Soc.*, Aug. 5, 1925) H. S. Taylor presented the results obtained by Marshall and Taylor, which show that ethylene, carbon monoxide, oxygen, and nitrous oxide will react at room temperatures with hydrogen atoms, produced by collisions of hydrogen molecules with excited mercury atoms. Carbon dioxide and nitrogen apparently do not so react. These experiments were made at pressures which averaged half an atmosphere, whereas all previous experiments were made at pressures of the order of a few mm. of mercury. The rapid velocities of the reactions which they observed lead them to suggest that a type of chain mechanism is effective in these reactions.

Finally, it may be mentioned that Franck (*loc. cit.*) suggested the following explanation of the emission of electrons from hot bodies. The thermal energy of the atoms results in the excitation of many atoms, and there must be equilibrium between this and the reverse processes. The frequency of the radiationless transitions is great compared with the number of transitions accompanied by radiation. At the surface of a metal, or of a metallic oxide, all quantum transitions whose energy changes are greater than the work of liberation of an electron from the surface will produce emission of electrons. This theory avoids the difficulty of the conception of free electrons inside a substance, and should therefore apply equally well to metals and to metallic oxides. It is somewhat similar to Richardson's theory of thermionic emission in that the resultant emission of electrons is dependent on the energy density of the temperature radiation, and varies in the same way with temperature. It has the advantage that it predicts a much larger emission of electrons than Richardson's theory, and presumably would account for the Maxwell distribution of velocities, owing to the thermal equilibrium inside the substance, in all cases.

It is clear that collisions of the second kind enable us to account for many complex phenomena, and there is certainly much scope for further research in this branch of physics.

PHYSICAL CHEMISTRY. By W. E. Garner, M.Sc., University College, London.

Photochemistry.—At a meeting of the Faraday Society at Oxford, October 1st and 2nd, 1925, a series of papers was read which surveyed the whole field of Photochemistry. The papers may be classified broadly into the three main groups concerning respectively the Einstein law, the kinetics of photochemical reactions, and the radiation hypothesis.

The Einstein Law.—The law of photochemical equivalence has stimulated research in photochemistry to an extraordinary degree, and has led to a large number of investigations on the quantum efficiency of photochemical reactions. Except for a comparatively few reactions, it has been shown to break down when applied to the complete photochemical change. As Warburg showed, it is exactly followed for HBr and HI decomposition, where two molecules decompose for every quantum absorbed; but, in the majority of photochemical reactions, the quantum efficiency is either very much greater or very much smaller than that anticipated from the Einstein law. Thus for H_2 and Cl_2, one quantum of 420 $\mu\mu$ converts 2,700 molecules, while for maleic to fumaric acid in water one quantum converts 0·04 molecule.

The quantum efficiency varies with the wave-length; for $O_2 \rightarrow O_3$ an increase from 1·7 for 2·53 $\mu\mu$ to 3·1 for 2·09 $\mu\mu$ is observed. Also, as Winther pointed out, the quantum efficiency decreases with increasing energy at constant wave-length. This is found for $O_3 \rightarrow O_2$, H_2O_2 in aqueous solution, green leaves, and oxidation of HI in aqueous solution (*Z. physikal. Chem.*, 1924, **108**, 236). These facts are all in opposition to the claim that the Einstein law is valid for the complete photochemical change.

Prof. Allmand, in his address, showed that the Einstein relation can only be strictly applied to the primary process by which the light is absorbed; the subsequent chemical changes may not follow stoichiometrically, and the number of molecules undergoing chemical change may bear no simple relationship to the number of quanta of light absorbed. The "activated" molecules may either undergo chemical change, or may revert to their initial unactivated condition by the loss of the absorbed energy as heat or by its emission as fluorescence or phosphorescence. When the latter processes occur to an appreciable extent, if at the same time the change be endothermic, the quantum efficiency is found to be low. An additional cause for departure from the law occurs for exdothermic reactions accelerated by light. Here, the part played by the energy liberated during the chemical change may completely mask the primary effect due to the absorption of radiation. The liberated chemical energy may activate further molecules giving rise to the so-called chain reactions which possess a high quantum efficiency. Add to these factors the possibility that one molecule may absorb more than one quantum, and it becomes evident that no simple relationship, which is applicable to all photochemical reactions, can exist between the quanta absorbed and the amount of chemical change.

Mechanism of Photochemical Reactions.—Franck discussed the question of the conversion of the activation energy into chemical energy. According to the view of Stern and Volmer (*Z. f. Wiss. Photographie*, 1920, **19**, 275), this occurs only when the activated molecule collides with another atom or molecule during the period of excitation. Otherwise the energy is emitted as fluorescence, which is the more intense the lower the pressure. The possibility of photochemical dissociation occurring as one elementary act, *i.e.* without collision with molecules which take no part in the reaction, depends upon the effect of electronic activation on the strength of the chemical linking. Evidence bearing on the effect of activation on the strength of the chemical linking may be obtained from molecular spectra. For example, Hg_2 gives molecular band spectra on the long wave-length side of the atomic lines. According to the theory of band radiation, this means that the atoms in the activated molecules are closer together than in the inactivated state. For the halogens, on the other hand, Mecke (*Ann. d. Phys.*, 1924, **71**, 104), has shown that the binding is greatly weakened on excitation, since a long series of absorption bands stretch towards the long waves. In this case, the molecule may take up so much oscillation energy that it may dissociate into a normal and an activated atom without the intervention of a molecular collision. This type of molecule would be expected to give rise to a monomolecular reaction.

The homopolar type of molecule, *e.g.* nitrogen, oxygen, carbon compounds, etc., where it is assumed that several electrons are held in common, molecular activation will not necessarily affect the strength of linking. Such molecules cannot separate adiabatically into two atoms. The dissociation of these molecules cannot occur photochemically, but only through the agency of collisions.

There would appear to be no direct relationship between the energy of activation and the work of dissociation of a molecule into two normal atoms. A hydrogen molecule can absorb an amount of energy which is five times as large as the work of dissociation. The absorbed energy, especially at low pressures, is emitted as fluorescence, or else is degraded to thermal energy. Neither does the heat of activation of a bimolecular thermal reaction correspond with the work of dissociation, or energy of linking of the molecule undergoing change, as was shown by Bowen in a paper on photochemical thresholds.

Sensitised Reactions.—In these reactions, one type of molecule absorbs light without decomposition, while another substance also present undergoes a chemical reaction at the expense of the energy absorbed by the former. One of the most thoroughly investigated examples is the decomposition of ozone sensitised by chlorine. For each molecule of chlorine activated two molecules of O_3 are decomposed. The amount O_3 decomposed is independent of the chlorine concentration. It thus follows that collisions between activated and normal chlorine atoms must be perfectly elastic, and that an activated chlorine atom possesses a long life at low pressures.

One of the best known of this type of sensitised change is that of Franck and Cario, in which mercury atoms activated by light cause the dissociation of hydrogen molecules (*Z. physik.* 1922, **12**, 162). Taylor and Marshall have extended this type of sensitisation to the interaction between hydrogen atoms produced by mercury vapour illuminated with $\lambda = 2536{\cdot}7$, and ethylene, carbon monoxide, oxygen, and nitrous oxide.

A very interesting type of photosensitisation has been investigated by Baur and his colleagues. Uranyl salts, or zinc oxide, when sensitised by light in solutions of organic bodies, are capable of bringing about chemical changes which are analogous to those occurring at the anode and cathode during electrolysis. Thus, an atom of uranium under the influence of light acquires a polarity which renders it at the same time an oxidising and a reducing agent. For example:

$$U^{VI} + h\nu = U^{VI}\,\overset{\oplus}{\ominus}\,.$$

this undergoes change with acetic acid into CH_4 and CO_2, thus:

$$U^{VI}\begin{cases}\oplus + CH_3\cdot COO' = CH_3\cdot COO \\ \ominus + H^{\cdot} + CH_3\cdot COO = CH_4 + CO_2\end{cases}$$

Zinc oxide in the presence of methylene blue undergoes photolysis according to the reaction:

$$ZnO\begin{cases}\oplus + \text{methylene blue} \rightarrow \text{products of oxidation.} \\ \ominus + \text{methylene blue} \rightarrow \text{leuco compound.}\end{cases}$$

Baur concludes that photolysis is a process of molecular electrolysis.

Degradation of Energy of Activation by Collision with Foreign Molecules.—Kistiakowski and Bodenstein have shown that activated O_3 molecules are dissociated by collision not only with O_3 molecules according to the equation: $O_3' + O_3 \rightarrow 3O_2$, but also lose their energy by collision with other gases without reaction occurring. The loss of energy of activation by collision is greatest in the presence of O_2 and least in the presence of helium and argon. The photochemical change thus proceeds with greater speed when helium or argon is the diluent gas than in the presence of oxygen. Similar results have also been obtained by Griffith and McKeown for the thermal reaction at 100°. The velocity of decomposition of ozone is more rapid in the presence of excess of nitrogen or helium, than in the presence of oxygen.

The foreign gases in these mixtures may be said to function as negative photocatalysts.

The Radiation Hypothesis.—Neither the collision theory nor the radiation hypothesis appears to yield very convincing mechanisms for monomolecular reactions. Perhaps this should be taken as indicating that ideal monomolecular reactions are figments of the imagination. The chief difficulty is that the rate of reaction calculated on either view is much too small. For the only reaction which is now considered to be a monomolecular reaction, *viz.* the dissociation of N_2O_5, the calculated rates of reaction are 1×10^8 and 1×10^6 times too low respectively. By the help of somewhat doubtful subsidiary hypotheses, Tolman, G. N. Lewis, and W. C. M. Lewis have been able to explain the discrepancy in the case of the radiation hypothesis. The assumption is made that light from a broad band or from a wide range of bands is effective in producing chemical change. For the collision theory, the discrepancy was removed by Christiansen and Kramers by assuming that the energy of activation was transferred very rapidly from one molecule to another after the collision. In this manner, the available collision energy is used over and over again in the promotion of chemical change. A similar assumption was made by Tolman in an elaboration of the radiation hypothesis. He assumes that the activating radiant energy is emitted simultaneously with the absorption. Rice, adopting this suggestion, postulates high absorption and reflection co-efficients for the light effective in causing chemical change. This view can be tested experimentally, since it requires metallic reflection from the gas surface. Rice suggests that this may be the reason why illumination by light of the wave-length corresponding to the critical increment does not in general accelerate the chemical reaction.

L. S. Ornstein, adopting Franck's view, that photochemical change and chemiluminescence are thermodynamically reversible phenomena, showed that if a "monomolecular" reaction followed the course

$$(1)\ A + h\nu \longrightarrow B \text{ (activated)}$$
$$(2)\ B + B \longrightarrow C + C + A$$

where C and C result from the dissociation of one of the activated B atoms, that the correct order for the rate of reaction can be obtained. This in the strict sense of the word is not, however, a mechanism for a monomolecular reaction.

BIOCHEMISTRY. By R. Keith Cannan, M.Sc., University College, London.

Biological Oxidation-Reduction.—The development of this subject is at an interesting stage. There can be read into most of the recent work the appreciation of a distinction which is of fundamental importance to the theoretical analysis of the problem. It is now generally felt—if not generally expressed—that we have to deal with two separate phenomena—the activation of the molecule oxidised and the activation of the molecule reduced. Thus, in the special case of aerobic oxidations, we have to consider the activation of both hydrogen (in Wieland's sense) and oxygen. The analysis is of immediate practical value, for it warrants the separate investigation of each hypothetical process. The problem may be broadly stated in terms of the experiments involved. We have to study, first, the mechanism of oxidation of organic substances in biological systems in the absence of oxygen. For our oxidising agent we employ a substance which we may take to be already " active." Such reagents are methylene blue and other reversible oxidation-reduction systems. Under these circumstances it may be hoped to derive information as to the activation of the "metabolite" by the biological agents present. The active oxidising agent is now replaced by oxygen—essentially a system of low activity—so that, the effect of the catalysts on the metabolite being known, we have the opportunity of deducing the effect of the tissue on the molecular oxygen.

By such a description the problem may be but poorly defined, yet, it is hoped, there has been emphasised the essential unity of biological oxidation-reduction, a unity which must not be lost sight of in the consideration of individual experiments.

Oxidation-Reduction in Anaerobic Systems.—In the separate discussion of anaerobic and aerobic processes, the reflection is pertinent that the former are probably more fundamental characteristics of vital activity than are the aerobic processes that may or may not accompany them. The living cell is to be regarded as a reducing agent—not merely as a reducing agent for oxygen. It will be recalled that Pasteur recognised in the anaerobic fermentation of sugar by yeast an almost perfect substitute for respiration.

The conception of the reversible change from methylene blue to methylene white as one involving two equivalents of hydrogen has become the conventional statement of the theory of Wieland respecting the mechanism of biological oxidation. In this view, the reducing enzymes of the cell—the succindehydrase of Batelli and Stern (*Ueber der mechanismus der oxidationsvorgange in Tierorganismus*, Jena, 1914), the Schardinger enzyme of milk (Wieland, *Ann.* **436**, 229), the reductases of yeast (Harden and Norris, *Biochem. Journ.*, 1914, **8**, 100), and the reducing enzymes of muscle (Thunberg, *Skand. Arch. Physiol.*, **40**, 1)—are able to catalyse the oxidation of favourable substances (aldehyde, succinic acid, purines, etc.), by methylene blue, by reason of their activating hydrogen atoms in the molecules of these substances. The methylene blue, considered as an active oxidant, is called a " hydrogen acceptor," the activated organic molecule becomes a " donator," and the tissue catalyst is variously described as a " dehydrogenase," " hydrogen transportase," and " oxidase."

The active hydrogen theory of Wieland (*Ber.* 55B, 3639) has been generally adopted by workers in anaerobic oxidation and, in particular, has received support from the work of Thunberg (*loc. cit.*). The " methylene blue technique " devised by this worker has already been widely applied to miscellaneous problems such as the comparison of the activity of the dehydrogenases of normal and cancer tissue (Fleish, *Biochem. Journ.*, 1924, **18**, 294, and Voegtlin, Johnson, and Dyer, *Journ. Pharm. and Exp. Ther.*, 1924, **24**, 305), the effect of insulin on the enzyme activity (Nitzescu and Cosma, *C.R. soc. biol.*, 1924, **90**, 1077, and Rosling, *Arch. Skand. Physiol.*, 1924, **45**, 132), and the comparison of plain and striated muscle (Tsubura, *Biochem. Journ.*, 1925, **19**, 397). Whereas these investigations have yielded no startling results they have served to indicate the general success with which the Wieland theory may be applied. A particular service which the latter performs is the correlation of what often appear distinct and specific reactions. Thus it is known that milk will effect the Cannizzaro reaction with added aldehyde, will, in the presence of methylene blue, oxidise aldehyde and certain purines, will reduce nitrates in the presence of aldehyde or purine, and will oxidise nitrites if oxygen also is present. Dixon and Thurlow (*Biochem. Journ.*, **18**, 976) offer very good reason for the belief that these changes are all to be attributed to the activity of the one enzymic system. There is no reason to believe in the specific catalysts postulated by Haas and Hill (*Biochem. Journ.* **18**, 614), to explain the oxidising and reducing power of milk towards nitrite and nitrate respectively.

From time to time " active " oxidising agents other than methylene blue have been advocated, including *p*-phenylene diamine (Szent Gyorgi, *Biochem. Z.*, 1924, **150**, 195), and *m*-dinitro benzene (Lipschitz, *Z. Physiol. chem.*, **100**, 189).

There is a danger, however, in the comparison of the results of the use of different indicators, whose respective activities cannot be defined and whose equilibrium states (as expressed by their oxidation-reduction potentials) have not been accurately established (W. M. Clark, *Chem. Revs.*, **2**, April 1925).

Aerobic Oxidations.—The work at present being carried out at Cambridge on the oxidase of milk, to which reference has already been made, proves to be a very interesting study. For one thing, the activity of the enzyme has been studied both by the methylene blue technique and using oxygen as a hydrogen acceptor. In the latter experiments hydrogen peroxide is identified as a product of the reaction, being the expected product of the acceptance of hydrogen by oxygen. Moreover, the kinetics of the reaction aerobically and anaerobically are different. This difference can, however, be eliminated by the removal of the hydrogen peroxide by catalase as it is formed, and seems to be due definitely to the destruction of the enzyme by the peroxide. We may reasonably infer that the peroxide is a by-product in the reaction rather than the active agent. Another interesting example of the production of peroxide aerobically is furnished by the work of Avery and Neill (*Journ. Med.*, papers in vols. **39** and **41**), on cultures of pneumococcus.

Nitrate is reduced by milk and aldehyde, whilst nitrite is oxidised when air is further admitted. The latter reaction is found to involve two processes, because preparations of the enzyme which still oxidise aldehyde in the presence of oxygen cannot oxidise nitrite. The combined action of oxidase preparation and an animal peroxidase will, however, repeat the action of milk on nitrite (*Proc. Roy. Soc.*, **94B**, 1099). In this case, therefore, an activation of oxygen through the intermediate formation of a peroxide is necessary to the reaction.

Exception is taken by Warburg (*Biochem. Z.*, 1923, **142**, 518), and by Bach (*Ber.* 1924, **57B**, 735), to the view that oxygen is to be regarded merely as a hydrogen acceptor, though it would seem that their objections lose some force, if it be conceded, as indeed it must, that the activation of oxygen is in general essential to its efficiency as a hydrogen acceptor. It is here that the contending views of Wieland, Bach, and Warburg must ultimately be restated in such form as to remove the diverging emphasis which characterises them.

Bach adheres to his view that in aerobic oxidations the secret of the mechanism resides in peroxide formation, and the liberation of active oxygen when this peroxide is destroyed under the action of a peroxidase. Warburg is impressed with another aspect of " active " oxygen. In an extended series of researches (papers in *Biochem. Z.* during the last few years), he has demonstrated that the structural elements of the living cell are of special significance in respiratory processes. Indeed, he has, with remarkable success, applied the methods of surface catalysis to the problem and imitated many biological oxidations by means of oxygen at the surface of charcoal. Moreover, he emphasises the significance of iron, attributing oxygen power to specific iron containing surfaces of the cell.

Space forbids us extending the present discussion. The immediate problem in biological oxidation-reduction is the co-ordination of the conditions of surface effects, the rôle of iron, the peroxide theory, and the theory of Wieland. A more complete study can scarcely fail to permit their restatement in common terms. It is hoped, in an early review, to return to the subject of "biological oxygen," when we shall have to discuss in detail, not only the work mentioned above, but a considerable body of work on other oxidases and on certain auto-oxidisable systems.

GEOLOGY. By G. W. Tyrrell, F.G.S., A.R.C.Sc., Ph.D., University, Glasgow.

Igneous Rocks.—J. H. L. Vogt's memoir on "The Physical Chemistry of the Magmatic Differentiation of Igneous Rocks" (*Videnskapsselsk. Skr.*, 1, *Math.-Nat. Kl. Kristiania*, 1924, No. 15, pp. 132) seems to be the most considerable work on the subject since Bowen's *Later Stages of the Evolution of the Igneous Rocks* (1915). According to Vogt, differentiation chiefly consists in the separation of early-crystallised minerals rich in high M.P. components, or magma enriched in the constituents of these minerals by re-melting after gravitative subsidence (proto-enriched or monomineralic magma), from residual magma in which the low M.P. mix-crystal components are concentrated (eutectic-enriched or anchi-eutectic magma). Magmas of the first kind are therefore enriched in the Mg_2SiO_4 component of olivine, the $MgSiO_3$ component of pyroxenes, and the anorthite component of plagioclase; whereas the Fe_2SiO_4, $FeSiO_3$, and albite components are concentrated in the residual magmas along with excess silica and magmatic gases. This view is supported by a mass of statistical data, showing that the magnesian component of olivine becomes increasingly abundant relatively to the ferrous component, concomitantly with an increase in the amount of that mineral. Similarly the high M.P. components are enriched in the pyroxenes and plagioclases along with increasing proportions of these minerals. A large part of the memoir is devoted to a thorough discussion of the proto-enriched rocks, peridotites, pyroxenites, and anorthosites.

With regard to anorthosite, Vogt combats Bowen's view that these rocks originate by the accumulation of plagioclase crystals. He gives a calculation showing that plagioclases just sink in the primary magma. On subsidence the crystals are re-melted in depth, and anorthosites therefore crystallise from magma which is effectively molten. Anorthosites on this view are of very deep-seated origin, and this explains the absence of lavas and the rarity of dykes and chilled contacts. Anorthosites usually occur in regions of compression, and fissures opening towards the surface would quickly be clogged by the rapid crystallisation of this high-temperature magma. F. Loewinsson-Lessing ("The Problem of the Anorthosites and the Monomineralic Igneous Rocks," *Journ. Geol.*, **31**, 1923, pp. 89–105) brings forward somewhat similar considerations in support of the view that anorthosites are derived from effectively liquid magmas. This paper is valuable for its references to inaccessible Russian work on these rocks. W. N. Lodschnikow (*Journ. Geol.*, **33**, 1925, pp. 153–72) also vigorously combats Bowen's views on the origin of anorthosite, and attacks the whole theory of gravitative differentiation.

Vogt's memoir concludes with a section statistically discussing the composition of residual magmas, and giving a number of new average analyses of various igneous rock types. His earlier paper, entitled "Die physikalisch-chemischen Gesetze der Magmatischen Differentiation" (*Videnskapsselsk. Skr.*, 1, *Math.-Nat. Kl. Kristiania*, 1923, No. 17 (1924), pp. 35), is a preliminary and generalised statement of the conclusions given in detail in the work considered above.

A highly successful general discussion on "The Physical Chemistry of Igneous Rock Formation" was held on October 23, 1924, by the combined Faraday Society, Geological Society, and the Mineralogical Society (*Trans. Faraday Soc.*, **20**, 1925, pp. 414–501). It is here only possible to give the titles and authors of the papers read. After an introductory address by Sir J. S. Flett, dealing with the history of the subject, the present writer gave a review of recent work on the origin and differentiation of igneous rocks. Succeeding papers were by Prof. P. Niggli, on "Homogeneous Equilibria in Magmatic Melts and their Bearing on the Processes of Igneous Rock Formation"; Dr. W. A. Richardson, on "Some Ultimate Problems in Petrogenesis"; Prof. J. W. Gregory, on "Magmatic Ores"; Dr. J. W. Evans, on "Proposed Researches on the Chemistry and Physics of Igneous Magmas and Rocks"; Prof. C. H. Desch, on "The Theory of Crystallisation in Rock Magmas," who made an attack on the "reaction-principle" recently enunciated by Dr. N. L. Bowen, which was rebutted by Dr. Bowen in a vigorous written rejoinder; Prof. W. E. S. Turner, on "Some Physical Properties of Silicate Glasses, and their Possible Bearing on the History of Igneous Rocks";

Mr. A.F. Hallimond, on "The Formation of Eutectic and Similar Structures in Silicate Melts"; and Dr. A. Scott, on "Physical Chemistry and Igneous Rock Formation."

Dr. L. Milch has written a valuable review of the differentiation problem with many references to recent Continental work (*Geol. Rundschau*, **15**, 1924, pp. 318–40); and A. Schwantke has described the differentiation phenomena of the Hessian basalts (*Neues Jahrb. Beil.-Bd.*, **48**, 1923, pp. 260–73).

In a discussion of the xenoliths of the contaminated rocks of Huntly, Aberdeenshire, Dr. H. H. Read (*Geol. Mag.*, **61**, 1924, pp. 433–44) shows that the contamination process depends upon reciprocal reaction between the gabbro magma and the argillaceous xenoliths, whereby the magma becomes more acid, gaining alumina, potash, and soda from the xenoliths, and losing lime and magnesia to them, so that the xenoliths become more basic. A process of differentiation due to *gravitative cleansing* may follow as a result of the magma becoming lighter while the xenoliths simultaneously become heavier. The xenoliths must sink towards the base of the magma chamber, and may there form a layer of richly-magnesian magma from which pyroxenite may ultimately crystallise, with the concomitant formation of a granitic alumina-alkali-rich upper part. It is suggested that the great differentiated lopoliths of Sudbury and the Bushveld may be worth re-examination from this viewpoint; and it is interesting in this connection to find that almost exactly similar contamination phenomena as those of Aberdeenshire have been noted in the Bushveld complex (see SCIENCE PROGRESS, October 1924, p. 201).

An illuminating general and historical account of pegmatites is given by Prof. J. F. Kemp in his Presidential Address to the Society of Economic Geologists (*Econ. Geol.*, **19**, 1924, pp. 697–723).

In discussing the origin of lithium pegmatites containing such lithium-rich minerals as lepidolite, spondumene, amblygonite, and red and green tourmaline, W. T. Schaller (*Amer. Journ. Sci.*, **10**, 1925, pp. 269–79) gives reasons for believing that these dykes and veins are not the result of the original crystallisation of a magma unusually rich in volatile constituents, but that they are due to a later replacement, probably hydrothermal, of an earlier-formed rock essentially free from mineralised fluids. The Southern Californian field was specially studied. Here the characteristic structure of the pre-existing rock, graphic granite, can be identified in all the varieties of pegmatite rich in albite, muscovite, garnet, black tourmaline, and the above-mentioned lithium minerals, which now fill the dykes.

F. von Wolff has elaborated a new quantitative classification of igneous rocks, especially the younger volcanic rocks, based on an original mode of calculation of mineral norms from the chemical analyses (*Geol. Rundschau*, **13**, 1922, pp. 9–17. Also in *Vulkanismus*, Band ii, Teil 1, 1924). E. Lehmann has also propounded a new scheme of classification based on a method of calculation which attempts to elicit the true mineral mode from the analysis (" Die Quantitative Ermittlung des Mineralassoziation in den Eruptivgesteine," *N.J.F. Min. Beil.-Bd.*, 52, Abth. A, Heft 1, 1925, pp. 61–112). These attempts, along with the previous ones by Johannsen, Niggli, and Hommel, have only served to convince the writer that, after all, the norm system of calculation of the American Quantitative Classification conforms best with the physical chemistry of magmas, and is the best adapted for the comparison and collation of igneous rock analyses.

H. Suter has discussed the consanguinity relationships of the known provinces of the charnockite-anorthosite type in the light of Niggli's system of variation diagrams (*Schweiz. Min. u. Petr. Mitth.*, **2**, 1922, pp. 307–30). These provinces are assigned to the Pacific *sippe* ; but do not represent the most extreme members, as they possess certain characters faintly recalling those of the other two *sippes* (Atlantic and Mediterranean of Niggli).

The petrology of Mull, as expounded in the long-awaited Mull memoir (" Tertiary and Post-Tertiary Geology of Mull, Loch Aline, and Oban," *Mem. Geol. Surv. Scotland*, 1924, 445 pp.), is far too extensive a subject to be summarised in a paragraph or two. The Mull centre is perhaps the most complicated volcanic focus in the world which has been accorded such detailed description. Beside the detailed petrography, a large number of points in theoretical petrology are dealt with, as well as some new conceptions in volcanic geology.

Seven magma types have been distinguished ; and of these, four, the plateau magma type, the non-porphyritic central magma type (compact basalt, tholeiite, quartz-dolerite), intermediate to subacid magma type (craignurite, leidleite, etc.), and the acid magma type (felsite, rhyolite, granophyre), are believed to belong to a magmatic series, which has an almost " straight-line " variation diagram. Other magma series described are allivalite, eucrite, porphyritic central magma (dolerite, gabbro, basalt), and an alkaline magma (mugearite, syenite, trachyte). The plateau basalt magma is regarded as the parental stock ; and it is possible to arrange most of the Mull magmatic sequence into two cycles, each beginning with plateau basalt. The plateau, central, intermediate, and acid magma types manifested themselves in that order, and to explain this Bowen's differentiation scheme is accepted with the addition that the main reservoir was thrice charged and recharged with the parental magma.

A fine example of a gravitative differentiation column is afforded by the Glen More ring-dyke, in which transitions from granophyre to gabbro take place within a vertical distance of 1,500 feet.

In a description of the igneous geology of the Burntisland district (Fife), Dr. D. A. Allan (*Trans. Roy. Soc. Edin.*, **53**, pt. 3, 1924, pp. 479–501) discusses the relations of the Carboniferous volcanic necks, lava-flows and intrusions, and establishes a new type of basalt, the *Kinghorn* type. This rock carries phenocrysts of olivine and augite in nearly equal proportions contained in a basaltic groundmass with a considerable amount of dark glassy base. Its analysis shows that it has close affinities with the Hillhouse type of basalt, which, along with the Dalmeny type, is associated with it. Intrusive rocks belonging to these types also occur, as well as teschenites, olivine-dolerites, olivine-free dolerites, and quartz-dolerites. Both quartz-dolerites and olivine-dolerites participate in post-Carboniferous crustal movements, and therefore antedate them.

At one place on the margin of the Ballachulish granodiorite a "white granite," rich in pyrites, intervenes between the plutonic rock and the adjacent Appin quartzite. Dr. F. Walker (*Geol. Mag.*, **61**, 1924, pp. 550–4) shows that this acid band cannot be due to assimilation of the quartzite, as it is strongly chilled against the contact, and contains no traces of xenoliths ; whereas the granodiorite itself is hardly chilled at all against other contacts. Local differentiation of the granodiorite magma with the production of an acid margin, and the subsequent influx of sulphurous gases, is regarded as the cause of the "white granite."

Dr. Walker has also described four small granitic intrusions in Silurian strata at Broad Law, Midlothian; Priestlaw, in East Lothian ; Cockburnlaw and Lamberton Beach in Berwickshire (*Trans. Geol. Soc. Edinburgh*, **11**, pt. 3, 1925, pp. 357–65). Hornblende-biotite-granodiorite seems to be the dominant type in each intrusion. The Priestlaw mass has a "basic" margin, an augite-biotite-quartz-diorite ; and analyses of the main type and the marginal facies are given. The age of these masses is Post-Silurian and pre-Upper Old Red Sandstone.

In some further notes on the petrology of Penmaenmawr, H. C. Sargent points out that quartz, orthoclase, micropegmatite, and iron ores (both ilmenite and magnetite), increase in amount towards the summit of the mountain (*Proc. Liverpool Geol. Soc.*, **14**, 1924, pp. 82–98). Somewhat similar features also occur in the Graig Lwyd area of the intrusion, although some of the details vary. The differentiation is ascribed to the straining-off of residual liquid rich in volatile constituents, especially water and carbon dioxide. To the latter must be attributed the abundant auto-metamorphic changes which are to be found in the upper part of the mass, while the lower part, freed from these constituents, remains fresh.

An olivine-dacite lava, 500 feet thick, filling a depression in the basaltic plateau of Eastern Iceland, is described by Dr. L. Hawkes (*Quart. Journ. Geol. Soc.*, **80**, pt. 4, 1924, pp. 549–67). The lithoidal mass shows contorted flow banding in its upper part, and is encased in a shell of glassy material. The rock is petrologically interesting, for while it is a thoroughly over-saturated rock with 34 per cent. excess silica, it nevertheless carries phenocrysts of the iron olivine fayalite. A review of acid igneous rocks with phenocrystic olivine is given. Fayalite is evidently but little soluble in acid magmas, and may form a eutectic with silica, thus behaving differently to forsterite.

Miss E. M. Guppy and Dr. L. Hawkes (*Quart. Journ. Geol. Soc.*, **81**, pt. 2, 1925, pp. 325–43) have described a remarkable composite dyke, exposed in a cliff section 2,400 feet in height, at Hökulvikurgil, Breithdal (Eastern Iceland). At one place it consists of seven members, dolerites alternating with quartz-porphyries, the central member being a quartz-porphyry. The evidence shows that the acid members were the products of one intrusive episode, whereby the magma forced its way up the centre and along the sides of the preceding basaltic infilling. The acid members are crowded with dolerite xenoliths which have not been derived from the visible internal contacts, as these are very sharp and clean-cut. They must therefore be due to the shattering of the basic rock in some other place, from which the fragments have been carried up by the quartz-porphyry. The whole sequence of events is very like that of the quartz-porphyry—dolerite intrusions of South Bute and Arran.

The earliest comprehensive British geological study in Iceland was made by Sir George Stuart Mackenzie in 1810; and his fine rock collection, made with unusual care, and accompanied by many perspicacious notes, is now in the Hunterian Museum of the University of Glasgow. Dr. M. A. Peacock, who was entrusted with the modern petrological description of the collection, has come to some important conclusions, which are set forth in two papers ("The Geology of Iceland," *Trans. Geol. Soc. Glasgow*, **17**, pt. 2, 1925, pp. 185–203; "A Contribution to the Petrography of Iceland," *ibid.*, pp. 271–333), the first of which describes and elucidates Mackenzie's original work, and gives a present-day sketch of the geology of Iceland.

In the petrographical paper a long series of rock types is described, ranging from ultrabasic olivine-rich basalts at the one end, through ordinary basalts, trachybasalts and trachyandesites, to very acid types of rhyolite at the other extreme. Thus, the long-lived fiction of the existence of two rock-types only, basalt and liparite, in Iceland, is laid to rest. It is shown that there must have been a long period of volcanic rest in the Pliocene. The most important result is that this period of quiescence separates two quite distinct igneous rock series, the Pre-Glacial or Tertiary on the one hand, and the Inter- and Post-Glacial on the other. By means of an ingenious variation diagram it is shown that the earlier series is over-saturated with respect to silica, whereas the younger is undersaturated, although it overpasses the saturation boundary at its acid end. Other results are the demonstration of an antipathetic relation between olivine and augite in the Interglacial ophitic basalts, which depends on the Bowen-Andersen effect ; and a new discussion of the problem of palagonitisation. Eight new complete analyses of Icelandic rocks are recorded.

While Prof. K. Keilhack's paper on " Die Geologischen Verhältnisse der Umgebung von Reykjavik und Hafnarfjördur in Südwest Island " (*Zeitschr. d. Deutsch. Geol. Ges.*, **77**, 1925, pp. 147–65) is, strictly speaking, stratigraphical, yet, as it deals almost entirely with igneous rocks, it is treated here in company with other papers on Icelandic geology. A notable feature is the full recognition by Keilhack of the tillite with its associated fluvioglacial sandstones and claystones, as *Alt-Diluvium*, instead of relegating this formation to a much more remote Pre-Glacial date as heretofore. The overlying glacially-striated *doleritlavas* (= " grey basalts " of Pjeturss) of Rejkjavik and its environs, are recognised as a series of enormous lava streams which have their origin in volcanoes now buried under the ice sheets of the Geitlandsjökull and the Langjöjull. An excellent geological map on the scale of 1 : 50,000 has been made, and this will prove of great service to geologists visiting the capital of Iceland.

The lavas of the island of Ischia have been described by E. Lehmann (*Zeitschr. f. Vulk.*, **8**, 1924, pp. 150–71) as phonolites of various types, of which several new analyses are given. The province shows a combination of Mediterranean (Niggli) and Atlantic characters, and is thereby distinguished from the province of the Phlegrean Fields (Mediterranean), and from that of Pantellaria and Linosa (Atlantic), between which it forms a transition.

R. A. Sonder has described the geology and petrology of the island group of Milos in the Ægean (*Zeitschr. f. Vulk.*, **8**, 1925, pp. 181–237). On a basement of crystalline schists there rests

Cretaceo-Eocene limestones and marls, and a volcanic series of Upper Pliocene age. The lavas are of calci-alkalic characters, and consist of plagioliparites, dacites, and andesites, of which nine new analyses are given. The origin of South Ægean vulcanicity is the inner marginal flexure of the fold-arcs of Southern Greece. The volcanoes have been built on the borders of an old crystalline massif, and in their extrusion have taken advantage of a fissure system already established in Miocene times, and associated with the flexure movements.

E. Hermann's work on the igneous rocks of the Arabian Desert (*N.J.F. Min.*, *Beil.-Bd.*, **51**, 1924, pp. 302–50), by which he means, according to the appended map, the Egyptian desert west of the Red Sea, is based on the collections of G. Schweinfurth between 1877 and 1885. Granites, monzonites, diorites, and gabbros, with their respective dyke rocks, and in some cases the corresponding lavas, are described ; but beyond a vague reference to " Gebirge aus altpaläozoischen Eruptivsmaterial gebildet," no indication of age is given. The alkali-granite massif of Gharib Dara represents an alkalic region which may be of comparatively recent age, comparable to the already known alkalic provinces scattered over North Africa.

Prof. F. F. Grout has summarised the petrography and petrology of the Vermilion batholith, the largest granite mass (Pre-Cambrian age) in Minnesota (*Journ. Geol.*, **33**, 1925, pp. 467–87). In places it has differentiated marginally into banded rocks, comprising syenites, shonkinites, pyroxenites, and even magnetite-rock, an uncommon series in connection with granitic differentiation. One of the special types, a shonkinite (Basswood type), is described in a separate paper (*Amer. Journ. Sci.*, **9**, 1925, pp. 472–80). This is a spotted rock with a little primary quartz, the spotting being due to poikilitic felspars. A convection circulation past the cooling walls of the batholith is postulated to account for the almost vertical position of the banded differentiates.

I. S. Allison has described another Minnesotan granite batholith, that of the Giant's Range, which lies between the Mesabi and Vermilion iron-mining districts, and is also of Pre-Cambrian age (*Journ. Geol.*, **33**, 1925, pp. 488–508). Its outcrop is a narrow belt striking north-east parallel to the adjacent schists, and occupies about 1,000 square miles. Differentiation has produced rocks ranging from diabase and shonkinite to soda-granite.

The petrographical chapter in that magnificent monograph by A. L. Day and E. T. Allen, entitled " The Volcanic Activity and Hot Springs of Lassen Peak " (*Carn. Inst. Washington, Publ.*, No. 360, 1925, 190 pp., 13 pls., 81 figs.) contains many new points of interest, although perhaps no American volcano has been so fully studied petrographically and chemically. Fifty-four analyses of the lavas have now been published, and they fall into well-defined groups corresponding to the five types: rhyolite, dacite, andesite, quartz-basalt, basalt; forming a well-graded differentiation series as shown by the silica variation diagram. Lassen Peak is interpreted as an old dying volcano; its greatest period of activity has passed long since; and its products are characteristic of a thoroughly differentiated magma.

Alkali-granite, nepheline-syenite, canadite, and foyaite are described by G. A. Molengraaf and A. L. Hall (*Kon. Akad. v. Wetensch. Amsterdam, Proc.*, **27**, 1924, pp. 465–86) as small bosses and dykes intrusive into the Witwatersrand System, and the dolomite member of the Transvaal System, at Vredefort. The nepheline-syenite dykes at Rietfontein are believed to be due to local desilication of alkali-granite by the dolomite formation into which it is intruded.

A contribution to the petrography of recent lavas from the volcanoes of Kamchatka is given by T. A. du Rietz (*Geol. För. Stockholms Förh.*, **46**, 1924, pp. 418–38). The later lavas consist mainly of pyroxene-andesites and olivine-andesites of bandaite type; among the older flows olivine-basalt is frequently found. The consanguinity of these lavas with those of the whole circum-Pacific volcanic girdle is recognised.

In his "Geology of American Samoa" (*Publ. No.* 340, *Carn. Inst., Washington*, 1924, pp. 95–143), Prof. R. A. Daly describes the petrography of a series of typical "oceanic island" lavas, consisting of basalts and trachybasalts, limburgitic basalt, trachyandesite (in dykes), associated with trachyte and quartz-trachyte. A coarse olivine-gabbro, probably the infilling of a volcanic neck, is the only rock of plutonic habit. The chemical characters of this assemblage are illustrated by a series of ten new analyses contributed by Dr. H. S. Washington. Prof. Daly derives the suite by local differentiation from the general substratum of basalt below the earth's crust. The concentration of magmatic gases may have aided in the separation of the trachytic phase, which was accompanied by violent explosive action with the formation of large masses of breccia around the vents.

An almost exactly similar suite to that of Samoa is described by Prof. Daly from Ascension (*Proc. Amer. Acad. Arts and Sciences*, **60**, 1925, pp. 1–8). Here again, basalts, trachybasalts, and trachyandesites are associated with trachytes and quartz-trachytes (with obsidian as chilled phases). Numerous plutonic types, including various granites quartz-syenite, diorites, gabbro, olivine-gabbro, and wehrlite, occur as xenoliths in the lavas, and as fragments and boulders in the tuffs. Prof.

Daly maintains that their trachytes are differentiates from common basalt; that their separation has been dependent on the upward movement of fluids, both liquid and gaseous; and that the active gas, probably "water-gas," was largely resurgent, *i.e.* derived from the rocks surrounding the magmatic focus.

San Felix and San Ambrozio are small volcanic islands in the South Pacific 500 miles W. of Chanaral on the Chilean coast. Their geology has been described by B. Willis, and the petrography of the lavas and tuffs by H. S. Washington (*Bull. Geol. Soc. Amer.*, **35**, 1924, pp. 365–84). Tephritic basalt, nepheline-basanite, and trachyte are the lavas described and analysed. All these rocks are rich in alkalies, especially soda. High titanium and phosphorus are also features of chemical interest. In these characters the lavas of these Chilean islands differ widely from those of other Pacific islands, in which there is abundance of normal basalt and trachybasalt. But as San Felix and San Ambrosio are probably merely the peaks of a gigantic volcano rising from profound depths, the lower parts hidden beneath the ocean may contain the basaltic foundation.

N. E. A. Hinds describes new occurrences of melilite- and nepheline-basalts in Hawaii (*Journ. Geol.*, **33**, 1925, pp. 526–39). These rocks appear to belong to the main eruptive complexes, and are not associated with minor episodes at subordinate centres subsequent to the main eruption. The origin of these highly specialised types is ascribed to the operation of Bowen's reaction principle in an alkali-rich magma.

PLANT PHYSIOLOGY. By Prof. Walter Stiles, Sc.D., University College, Reading. (Plant Physiology Committee.)

Permeability.—Since this subject was last reviewed in these pages some four or five years ago, the output of published researches on the problems of cell permeability has been very considerable, so that it is here possible to do no more than discuss a few of the more representative pieces of work published during the last few years which advance our knowledge of the subject.

It will be convenient to consider first the question of the permeability of plant cells to electrolytes, as much attention has been devoted to the penetration and absorption of ions. In a paper on "Direct and Indirect Determinations of Permeability," W. J. V. Osterhout (*Journ. Gen. Physiol.*, **4**, 275–83, 1922) recorded the results of qualitative examination of the composition of the sap of cells of *Nitella* after they had remained for a time in various solutions. Such cells were found to absorb nitrate rapidly from a pure solution of sodium nitrate, but that in a so-called balanced solution containing both sodium nitrate and calcium nitrate the penetration of nitrate into the cell is much slower. In a second contribution, dealing with the salt relations of another plant, the marine alga *Valonia macrophysa* (" Some Aspects of Selective Absorption," *Journ. Gen. Physiol.*, **5**, 25–230, 1922), the sap was analysed quantitatively, and its composition compared with that of the sea-water in which the plants were growing. The investigation showed that some ions, namely, sodium, calcium, magnesium, and sulphate, are present in a lower concentration in the cell sap than in the surrounding sea-water, whereas the concentration of potassium in the sap is much in excess of the concentration of this ion in the surrounding sea-water. The concentration of chloride was found to be much the same within and without the cell. In a later paper the same writer returns to this subject (" On the Importance of Maintaining certain Differences between Cell Sap and External Medium," *Journ. Gen. Physiol.*, **7**, 561–4, 1925). It is recorded that if the difference in composition of the cell sap and the surrounding medium is abolished by placing the cells in the sap of their own species, they quickly die. That this result is not due to bacterial action in the expressed sap used was shown by employing sap which had been boiled and filtered, in which the cells die as rapidly as in the unboiled sap. But the addition of salts to the expressed sap used, so as to make a balanced solution, removed the toxicity, whence it appears that death of cells in sap of their species is due to lack of balance, and that the maintenance of differences in composition of sap and external medium is a necessity for the existence of the cells.

Work on the penetration of ions into plant cells has been carried out on similar lines by Matilda M. Brooks. In a paper on " The Penetration of Cations into Living Cells " (*Journ. Gen. Physiol.*, **4**, 347–9, 1922), the results are recorded of experiments in which cells of *Nitella* were placed in different hypotonic solutions, and after a time the cell sap was removed by means of a capillary pipette and examined spectroscopically. Such experiments showed that the protoplasm of *Nitella* cells is normally permeable to lithium, ceasium, and strontium ions, but that penetration is much less rapid from a balanced solution, one, that is, in which the salt under investigation is presented to the cells in sea-water.

The same worker has also investigated the penetration of acids into *Valonia* (" Studies on the Permeability of Living and Dead Cells. I. New Quantitative Observations on the Penetration of Acids into Living and Dead Cells," *Public Health Reports*, 1449–70, 1923). By determination of the hydrogen-ion concentration of the cell sap of *Valonia ventricosa* immersed in solutions of acids of different types, the penetration of a number of acids through the protoplasm of this species was investigated. It was found that the presence in the sap, before exposure to the acid, of bicarbonate, had a marked influence on the apparent rate of change of the hydrogen-ion concentration of the sap, the P_H value of which does not fall below 5·2 until the whole of the bicarbonate present has been removed by the penetrating acid. The acids examined were found to fall into two groups. One group includes hydrochloric, sulphuric, nitric, phosphoric, arsenic, oxalic, citric, tartaric, and mono-, di-, and tri-chloracetic acids. These acids liberate carbon dioxide from the bicarbonate in the cell and accordingly appear to penetrate more slowly than they actually do. Acids of the other group are unable to bring about the release of carbon dioxide, and the rate of change of hydrogen-ion concentration of cells immersed in any of these indicates that the acid is absorbed very rapidly. This group includes acetic, salicylic, butyric, and benzoic acids. The behaviour of dead cells is somewhat similar to that of live ones, so it is concluded that the living protoplasm is not the only agency in the cell determining rate of penetration of acids into the cell.

In a further study on the permeability of *Valonia*, the same worker has investigated the penetration of bicarbonates into this plant (" Studies on the Permeability of Living and Dead Cells. II. Observations on the Penetration of Alkali Bicarbonates into Living and Dead Cells," *Public Health Reports*, 1470–7, 1923). It was found that when living *Valonia ventricosa* is placed in sea-water containing alkali bicarbonates, carbonic acid rapidly enters the plant, while the sap, when freed from carbon dioxide, is found to have become more alkaline, thus indicating the penetration of alkali ions through the protoplasm. The addition of potassium bicarbonate to sea-water is more effective than sodium bicarbonate in speeding up the entrance of carbonic acid and increase in alkalinity, whence it is concluded that the potassium ion affects the permeability of the protoplasm more than the sodium ion. It is important that this behaviour is not observed with dead cells. Although the increase in alkalinity of the carbon dioxide free sap is not so marked when citrate, acetate, or chloride is used instead of bicarbonate, in all cases the potassium salt is more effective than the corresponding sodium salt in producing this alkalinity.

Further experiments were made by the same author on the penetration of arsenic into cells of *Nitella* (" The Penetration of Arsenic into Living Cells," *Proc. Soc. Exper. Biol. and Med.*, 20, 39–40, 1922), from which it appears that the arsenic of atoxyl penetrates into cells of *Nitella*, and that this penetration depends on the hydrogen-ion concentration of the surrounding medium, but it is not clear whether this apparent relation between the penetration of the arsenic and hydrogen-ion concentration is due to the influence of the latter on the degree of dissociation of the atoxyl or to changes produced in the permeability of the protoplasm.

The permeability of the protoplasm of *Nitella* has also been the subject of investigation by D. R. Hoagland, A. R. Davis, and J. C. Martin (" The Composition of the Cell Sap of the Plant in Relation to the Absorption of Ions," *Journ. Gen. Physiol.*, **5**, 629–46, 1923). Analysis of the cell sap showed that all the principal ions present, namely, potassium, sodium, calcium, magnesium, chloride, sulphate, and phosphate, are in very much higher concentration in the sap than in the water surrounding the plants. Determination of the electrical conductivity of the extracted sap indicates that these inorganic constituents are indeed present in the ionic condition. It thus appears that a difference in concentration of the same ion is maintained on the two sides of the protoplasm, a conclusion in agreement with the results obtained by Osterhout with *Valonia*, to which reference has already been made. It thus appears that an ion can penetrate into a cell from an external solution of lower concentration into the cell sap of higher concentration in regard to that ion.

The writers also investigated the penetration of nitrate into cells of *Nitella*, and found that the penetration of this ion is much influenced by the hydrogen-ion concentration of the solution, penetration being much more rapid from a slightly acid solution than from one with an alkaline reaction.

In a later paper Hoagland and Davis (" Further Experiments on the Absorption of Ions by Plants, including Observations on the Effect of Light," *Journ. Gen. Physiol.*, **6**, 47–62, 1923) extended their observations on the penetration of ions into *Nitella* cells. They found that the conditions of illumination to which the cells were subjected influenced very considerably the penetration of ions from dilute solutions into the cells. Thus, when the cells were immersed in a solution of 0·015 m. potassium dihydrogen phosphate containing various amounts of potassium chloride (0·0005 m., or 0·001 m.), it was found that in the dark only very small quantities of chlorine were absorbed by the cells, but that with exposure to various periods of illumination the quantity of chlorine absorbed increased along with the duration of the illumination. When potassium bromide or potassium iodide was employed in place of the chloride, the same result was obtained, although less iodide was absorbed than chloride or bromide.

An antagonistic action between ions was observed in experiments with *Nitella*, and a number of observations were made on the effect of the presence of various salts on the absorption of the nitrate ion. It was found that potassium chloride, potassium bromide, and potassium iodide have a very marked effect in decreasing the rate of absorption of nitrate, while potassium sulphate is much less efficient in this respect. The authors conclude that three possible types of antagonism may exist : kation antagonistic to kation, anion to anion, and kation to anion.

In a long paper on the action of salts on protoplasm, H. Kaho (" Über die physiologische Wirkung der Neutralsalze auf das Pflanzenplasma," *Univ. Dorpatensis Inst. Bot. Opera*, No. 18, pp. 167, 1923), the permeability of cells of red cabbage and *Zebrina pendula* leaves is dealt with. The determinations of the permeability of the cells in question to a number of neutral salts were made by means of Lundegårdh's tissue extension method. From the results of the measurements made, the author concluded that the penetration of neutral salts into the cell is a physico-chemical process depending on the " colloid-activity " of the salt, to which both ions of the salt contribute. The order of penetration of kations into the cells examined was found to be as follows in descending order of penetrating capacity : potassium, sodium, lithium, magnesium, barium, calcium, while the order in the case of anions was found to be iodide, bromide, nitrate, chloride, tartrate, sulphate. It is concluded that the penetration of neutral salts into the protoplasm depends on their capacity to alter the colloidal condition of the colloids of the surface layer of the protoplasm, the capacity of any salt in this respect being the sum of the capacities of the constituent ions. It is thought that the action of kations is a coagulating, or de-swelling, one, and their action is to lessen permeability, whereas the action of anions is one of swelling or digesting, which results in an increase of the protoplasmic permeability. Toxicity of neutral salts is ascribed to their power to penetrate the protoplasm ; salts which enter the cell rapidly are the most toxic, those which penetrate slowly are comparatively harmless. It is thought that in the surface layer of the protoplasm the colloids present which are the subject of this salt action are particularly fatty substances.

Some observations of S. Prát on plasmolysis of *Spirogyra* cells (" Plasmolyse and Permeabilität," *Biochem. Zeitschr.*, **128**, 557–67, 1922) are worthy of note in this connection. The cells were plasmolysed in a number of different salts, and it was found that the degree of plasmolysis increases after a certain time when salts of monovalent ions are used, but decreases or remains constant when the plasmolysing salt possesses a divalent ion. In relation to the course of plasmolysis kations can be arranged in the series: potassium, sodium, calcium, magnesium, and anions in the series: nitrate, chloride, sulphate. The change in the degree of plasmolysis must be traced to exosmosis and to changes in the degree of hydration of the plasma colloids, enzyme actions in the cell and to other factors. The conclusions of Prát are thus not at variance with those of Kaho.

The penetration of dyes into cells has been investigated by Gladys M. Redfern, C. E. T. Mann, and Marian Irwin. The first-named writer ("On the Course of Absorption and the Position of Equilibrium in the Intake of Dyes by Discs of Plant Tissue," *Ann. of Bot.*, **36**, 511–22, 1922) showed that carrot-root cells absorb dyes to such an extent that when equilibrium is approached the concentration of dye within the cell is very much higher than outside it. Basic dyes exhibit this phenomenon much more markedly than acid dyes, and crystalloid or semi-colloid dyes than colloidal ones. Further, the proportion of the dye absorbed from a dilute solution is much higher than from a more concentrated solution, the amount of dye absorbed being approximately given by the adsorption aquation.

C. E. T. Mann ("The Antagonism between Dyes and Inorganic Salts in their Absorption by Storage Tissue," *Ann. of Bot.*, **38**, 753–77, 1924) showed that the absorption of a dye such as neutral red or methylene blue is much depressed by the presence of an inorganic salt, and that the depression is greater the greater the valency of the kation. Thus, 0·001 n. lanthanum chloride is more effective in preventing the entrance of methylene blue into cells of mangold than 0·025 n. ammonium chloride.

The contributions of Marian Irwin to the subject have dealt with the entrance of dyes into cells of *Nitella*. In the first paper ("The Permeability of Living Cells to Dyes as affected by Hydrogen Ion Concentration," *Journ. Gen. Physiol.*, **5**, 223–4, 1922) it is recorded that cresyl blue is unable to penetrate rapidly into the cells unless the hydrogen-ion concentration of the external medium is less than that of the sap, while the rate of penetration of the dye increases with increase in the P_H value of the medium. The observations were extended in a later paper ("The Penetration of Dyes as influenced by Hydrogen Ion Concentration," *Journ. Gen. Physiol.*, **5**, 727–40, 1923), and from the results obtained it is concluded that both the rate of penetration of the dye and amount of dye absorbed when final equilibrium is attained increase with increasing alkalinity of the medium, and this is thought to be due to an increase in active protein or other amphoteric electrolyte in the cell which can combine with the dye.

Finally, reference must be made to a paper by W. Ruhland

and C. Hoffmann (" Die Permeabilität von *Beggiatoa mirabilis*," *Arch. f. wiss. Bot.*, **1**, 1–83, 1925), in which the penetration of a large number of substances of various kinds into cells of *Beggiatoa mirabilis* was followed by a plasmolytic method. From the results obtained the authors conclude that the permeability of the cell to any substance is determined by the size of the molecule of the substance, not only for colloids but also for crystalloids. They thus conclude that the ultrafilter theory of permeability put forward some years before by the senior author is completely supported by their new observations.

PEDOLOGY. By G. W. Robinson, M.A., University College of North Wales, Bangor.

In writing for the first time on recent advances in pedology,[1] it is, perhaps, not superfluous to give some indication of what branch of science is included in this term. The study of soils, for it is of that we are speaking, dates back as an applied science for upwards of a century. Until comparatively recent years, soil investigations have had a distinctly practical bias, and our knowledge of soils has grown in directions different from those in which it would have developed if a purely philosophical viewpoint had been maintained. Even with this applied bias, considerable advances have been made in the fundamental knowledge of soils, but the present position is analogous to the possible position of geology if the subject had developed in close association with mining and quarrying.

Of late years it has been realised that even for the practical aim of aiding agriculture, the surest line of progress lies in studying soils by the methods of pure science. If the fundamental principles of the origin and constitution of soils are elucidated, then applications to practice must follow as corollaries.

Pedology, then, is the study of soils along the lines of pure science. In one aspect it is a branch of geology, since it concerns itself with the superficial strata of the regolith in which many of the most important processes in the cycle of weathering and denudation are fulfilled. In another aspect it is the study of the physical and chemical properties of a complicated colloidal system. In a third aspect it is the study of a complex flora and fauna in relationship to soil environment. These three aspects are closely interdependent, for a complete knowledge of the origins and metamorphoses of soils involves an understanding of soil constitution, which itself is closely related to soil microbiology.

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[1] From πέδον = soil or ground. Therefore, pĕdology, not pēdology.

The present review of recent work on pedology will therefore relate to those studies in which the subject is approached as a pure science. The writer feels justified in making this restriction, for the volume of research on soil problems in different countries has now reached such proportions that some division is both necessary and desirable.

International Society of Soil Science.—At the fourth International Pedological Conference, held in Rome in May 1924, it was decided to form an International Society of Soil Science. In passing, a word of regret may be expressed that the term "pedology" was not adopted instead of the clumsy phrase "soil science." The object of the new society is to promote the study of soils by the organisation of conferences, the formation of sectional commissions dealing with different aspects of the subject, and the publication of a Review in English, French, German, Italian, and Spanish. The headquarters of the new society are at the International Institute of Agriculture in Rome. The next congress of the society will be held at Washington in 1927.

Pedology as a Branch of Geology.—The significance of pedology as a branch of geology has been discussed by G. W. Robinson (*Geol. Mag.*, 1924, **61**, 444), who has given a short account of the climatic classification of soil developed by Glinka and the Russian school. One of the most signal services rendered by the Russian pedologists has been their insistence on the importance of studying soils in profile. Where the downward transportation of soil constituents by percolating waters has proceeded sufficiently, three soil horizons may be distinguished: namely, the A horizon, from which certain constituents have been removed by leaching; the B horizon, or zone of accumulation, in which there is a deposition of materials removed from the A horizon; and the C horizon, which is the parent material from which the soil has developed. These horizons are not distinguishable in soils which are in the early stages of development or exposed to intense surface erosion. The mature profile is governed by the character of the climate, and different rocks may, under the influence of the same climate, yield soil profiles which are essentially similar. The principal climatic provinces are distinguished by Glinka according to the types of profile associated with each.

Nomenclature and Classification of Soils.—The memoirs on the nomenclature and classification of soils presented to the Rome Conference have been published at Helsingfors by the Finnish Geological Commission, under the editorship of Dr. B. Frosterus (*Mémoires sur la Nomenclature et la Classification des Sols*). This volume gives an admirable conspectus of the different views held on this difficult problem. Whilst many of the memoirs show the influence of the climatological school

(Murgoci, Aarnio, Glinka), others describe systems of nomenclature and classification based on actual soil properties (Hissink, Christensen, Tesch).

Soil Classification on the Basis of the Character of the Colloidal Absorbing Complex.—Gedroiz (*People's* [*Russian*] *Commissariat of Agriculture, Agrochemical Division,* No. 38, 1925) has proposed a system of soil classification based on the character of the colloidal absorbing complex. His primary division is practically the same as one proposed by Ramann several years ago, namely, into base-saturated and base-unsaturated soils, or, as Gedroiz expresses it, soils which do not contain hydrogen ions in their absorbing complex, and soils which contain hydrogen ions in their absorbing complex. The saturated soils are further divided as follows: (*a*) Soils in which the principal cation associated with the colloidal complex is calcium, with magnesium in smaller amount and insignificant amounts of sodium and potassium. These are the well-known tshernosems or black earths. (*b*) Soils in which the principal associated cation is sodium, with the bivalent cations occupying a secondary place. These soils are again sub-divided according to the amount of soluble alkali salts present and according to the presence or absence of earthy carbonates. Amongst these soils are the " alkali " and saline soils.

Unsaturated soils fall into two sub-groups—namely, the laterites, found in the humid tropics, characterised by accumulation of residual sesquioxides and removal of silica, and the " podsols," found in colder humid climates, characterised by the leaching out of sesquioxides from the surface horizon and their accumulation in the illuvial horizon.

Podsol Profiles.—McCool, Spurway, Veatch, and Weidemann (*Soil Sci.*, 1923, **14**, 95; 1925, **18**, 181) have recently described soil profiles in Michigan which are essentially similar to those studied by the Russians under the name of podsols, *i.e.* soils in which, under the influence of acid percolating waters, there has been a removal of sesquioxides from the surface horizon and a deposition of these together with colloidal humus in the B horizon. The A horizon is distinguished by a bleached layer immediately below the turf layer in virgin soils. Edgington and Adams (*Soil Sci.*, 1925, **20**, 177), working on podsol profiles in New Hampshire, have studied in particular the vertical distribution of nitrogen. They have found that the nitrogen content decreases sharply in passing from the turf layer to the bleached horizon, rises again in the B horizon, and decreases again in what is apparently the C horizon. The nitrogen presumably runs parallel with the colloidal content.

Brown Earths in Finland.—A widespread type of soil in Western Europe is the so-called brown earth (Braunerde), which seems to be of the podsol type in that it tends to be depleted of exchangeable calcium in its surface layers but which differs from the true podsols in not showing a marked leaching of humus and the sesquioxides. The brown earths may thus be a transition series between the black earths and the podsols. Aarnio (*Proc. Intern. Soc. Soil Sci.*, 1925, **1**, 71) has described some brown earth profiles from Finland. These soils show a greater stability of the sesquioxides and the humus against leaching than is the case in podsols. In fact, in one profile of a soil under hazel forest, the differences in mineral composition between the different horizons are insignificant. The greater stability of these soils against leaching is correlated with the calcium content of the surface layer, which is maintained by the lime added annually by leaf fall. Where the forest trees are coniferous, the addition of lime by leaf fall is less and a podsol type of soil results.

Origin of Black Turf Soils of the Transvaal.—Marbut (*Soils of Africa*, Shantz and Marbut, New York, 1923), in a description of the soil of Africa, suggested that the widely occurring " black turf " soils of the Transvaal might be analogous to the black earths of Russia. Marchand (*S. Afric. Jour. Sci.*, 1924, 160) strongly opposes this view and attributes the character of these soils rather to the nature of the parent rocks than to the influence of climate. He points out that black turf soils and red clay soils can occur under the same climatic conditions. The controversy is of particular interest and certainly suggests that although the climatic classification is of value in certain regions, yet in others, the properties of soils can be more perfectly correlated with geology and topography.

Cartography of soils.—In the volume published by the Rumanian Geological Institute under the editorship of the late Prof. G. Murgoci (*État de l'Étude et de la Cartographie du Sol*, Bucharest, 1925), the different memoirs on this subject presented to the Rome Congress are collected together. The volume gives an excellent view of the state of pedological studies in different countries.

Constitution of Soils.—The properties of soils are largely governed by the fact that soil is a colloidal system in which the active colloidal constituents are the colloidal clay and organic matter, also called the colloidal adsorbing complex. Wiegner, Gallay, and Gessner (*Koll. Zeit.*, 1924, **35**, 313) have discussed the effect of cations on the properties of clay suspensions. It is concluded that the stability of clay suspensions is governed by the degree of hydration of the associated cations. The order for the monovalent ions in decreasing degree of hydration is Li, Na, K and NH_4, Rb, Cs, H, and for the bivalent ions, Mg, Ca, Ba. Thus a lithium clay suspension will be more viscous and more stable to electrolytic flocculation than a cæsium or hydrogen clay. The effect of added electrolytes on clay suspensions will be complicated by base exchange. For example, potassium chloride will have a greater effect on a calcium clay than on a potassium clay, owing to the displacement of adsorbed calcium in the former case. These ideas are further developed by Wiegner in a more recent paper (*Koll. Zeit.*, 1925, **36**, 341).

Clay as an Acid.—Hissink, in his classic paper on the adsorption processes in soils (*Int. Mitt. Bodenkunde*, 1922, **12**, 81), developed the conception of the acidic character of the colloidal complex of the soil. In his more recent papers (e.g. *Trans. Faraday Soc.* 1925, **20**, 551) he has further developed this point of view and has described methods of determining the reaction value of the soil acids which are not actually combined with bases. His results with Dutch soils show that even in soils which are in equilibrium with excess of calcium carbonate, only about 55 per cent. of the total acidity is neutralised. Complete neutralisation is only possible in the presence of a large excess of alkali. The position is analogous to the well-known case of the hydrolytic dissociation of salts of weak acids.

Among recent work on the acidic properties of clay, that of Bradfield (*Jour. Amer. Soc. Agronom.*, 1925, **17**, 553) demands special attention. His work relates to colloidal clay isolated centrifugally from Missouri soils. He has shown by conductometric titration that colloidal clay behaves similarly to weak acids. He has also studied certain artificial clays obtained by mixing colloidal solutions of silicic acid and the sesquioxides. The balance of evidence is in favour of regarding colloidal clays as composed of complex aluminosilicates rather than as "absorption compounds" or mixtures of the colloidal oxides. The reactions of colloidal clay appear to be chemical, with the restriction that these reactions are confined to the surface of the particles. It still remains to be settled whether the reacting surface is the surface of the colloidal aggregates, or the surface of primary constituent particles, as has been suggested by Wiegner.

On the reasonable assumption that colloidal clay is the result of the hydrolysis of crystalline minerals, it would be of interest to decide whether the production of the separate colloidal oxides is an intermediate stage or whether the formation of clay consists in a direct modification of the parent minerals.

The controversy between Joseph and Mukherjee on the reaction between silica and electrolytes (*Trans. Chem. Soc.*, 1923, **123**, 2022 ; *Nature*, 1925, **115**, 157) is of great interest in connection with the acidic properties of clays.

Constitution of Clay.—In the older literature, it is often assumed that kaolin is a characteristic constituent of clay. Recent work on the properties of clays has shown that many kaolins only possess to a small degree the properties associated with clays. Rieser (*Chemie der Erde*, 1925, **2**, 15) has found no evidence of the presence of kaolin among the products of the weathering of granite under peat. W. O. Robinson and Holmes (*U.S. Dept. Agric. Bull.* 1311, 1924) found no kaolinite or nontronite in colloidal clay, although some crystalline mineral fragments were present.

The emulsoid character of colloidal clay has been questioned by Powell (*Soil Sci.*, 1925, **19**, 407) on the grounds of the smooth character of the curve connecting temperature with the viscosity of clay suspensions.

Joseph and Hancock (*Trans. Chem. Soc.*, 1924, **125**, 1288) have correlated the colloidal properties of clay with the SiO_2/Al_2O_3 ratio, the more plastic clays showing the higher ratios. Anderson and Mattson (*Science*, 1925, **62**, 114) have found a similar relationship, using the ratio SiO_2/R_2O_3. Both pairs of workers used colloidal clay separates for their experiments.

Soil Physics.—The moisture relationships of soils have been under close study for the past few years by Keen and Fisher in this country, by Hardy in the West Indies, by Wilsdon in India, and by Thomas and Bouyoucos in the United States. One of the chief difficulties has been the devising of suitable constants to represent the relationships of soil to water. Constants such as the hygroscopic coefficient and the moisture equivalent are still in the trial stage. Their value is abated somewhat by the fact that they are obtained by conventional rather than by absolute methods. The relationships between the principal moisture constants of soils have recently been examined. Wilsdon (*Mem. Dept. Agric. India, Chem. Series*, 1921, **6**, 171) has discussed the well-known Briggs-Schantz formula, $M = 4{\cdot}3H + 21$, in which M is the maximum water-retaining capacity of a soil and H is its hygroscopic coefficient. He conceives the $4{\cdot}3H$ in the formula to represent the colloidally imbibed water and the 21 to represent the interstitial water. The latter point has been criticised by Keen (*Jour. Agric. Sci.*, 1924, **14**, 170). According to Wilsdon, the colloidally imbibed water is made up of the gel water associated with the structure of the colloidal reticulum and of vesicular water filling the interstices. Hardy (*Jour. Agric. Sci.*, 1923, **13**, 340) has suggested that the term $4{\cdot}3H$ might be replaced by P, the water content at which a soil-water paste begins to show external adhesion (point of stickiness). This represents the stage at which the colloidal reticulum is completely filled with water, and is a measure of the total imbibition capacity of the soil colloids. From the differing values which Hardy obtains for P/H he concludes that there are specific differences between soil colloids. The constant P may prove a useful single value measure of the colloidality of soils.

Vapour Pressure of Soils.—Puri, Crowther, and Keen (*Jour. Agric. Sci.*, 1925, **15**, 68) have investigated the relationship between vapour pressure and moisture content for a number of soils. The forms of the curves obtained are different according to the properties of the soils examined. It is shown that small changes in the atmospheric humidity, both near the point of absolute dryness and near the point of saturation, cause great changes in the moisture content of the soil.

Mechanical Composition of Soils.—G. W. Robinson (*Jour. Agric. Sci.*, 1924, **14**, 626) has investigated the mechanical composition of different soils, clays, and other granular materials. The particle size distribution can be represented by smooth curves. These curves, which are made to show the relationship between summation percentages and the logarithm of settling velocities in water, are generally of a sigmoid type in the case of materials of uniform origin. The steepest part of the curve indicates the " modal fraction." This appears to be near the lower end of the curve in the case of heavy clays, whilst in the case of mechanically disintegrated materials, such as ground slate, it is at the upper end of the range.

Soil Microbiology.—Space does not permit, on the present occasion, an adequate discussion of recent work on this branch of pedology. Reference may, however, be made to an excellent review of the present state of the subject by Waksman (*Soil Sci.*, 1925, **19**, 201).

ANIMAL NUTRITION.

By Herbert Ernest Woodman, Ph.D., D.Sc., School of Agriculture, Cambridge.

The Significance of Vitamins in Stock-feeding.—The recognition, during the second decade of the present century, of the essential rôle played by vitamins in the nutrition of growing animals not unnaturally gave rise to hopes that the information gained in biochemical research on this subject would prove of great practical utility in connection with the feeding of farm animals. It cannot be said, however, that these hopes have been realised. The vitamin hypothesis, whilst affording in part an explanation of the well-recognised effects of certain feeding-stuffs, has not led to any outstanding modification of the previously accepted principles of feeding practice. A short sketch of recent vitamin investigations on farm animals will serve to emphasise the correctness of this assertion.

As far back as 1915, Theiler and his associates carried out an extensive series of experiments with a view to ascertaining the vitamin requirements of cattle, goats, sheep, and horses. They drew the surprising conclusion that the requirements of these animals were so small, that it would be no easy matter to devise a ration of ordinary feeding-stuffs which would produce the symptoms usually ascribed to vitamin deficiency. Compared with small animals, such as rats, guinea-pigs, and pigeons, on which most of the vitamin research had been carried out, cattle and horses appeared to be relatively insusceptible to deficiencies of vitamins in the diet (*Report of the Director of Veterinary Research, Union of South Africa*, 1915).

These conclusions have been amply confirmed by the recent investigations of Orr and his co-workers at the Rowett Research Institute (J. B. Orr, *Agric. Progress*, vol. ii, 1925). Orr points out that the farm animal most likely to suffer from vitamin deficiency is the pig, partly on account of its rapid growth and partly on account of the fact that swine husbandry tends to proceed on more artificial lines than is the case with other classes of stock. Yet in experiments with pigs at the Rowett Institute, it has not been found possible to produce signs of malnutrition which could be attributed to deficiency of vitamins A and C. On the other hand, however, when kept on rations in which the *known* essential constituents (protein and mineral substances) were deficient or improperly balanced, the animals developed disorders resembling those attributed to lack of vitamins. It is clear from the Aberdeen work that the earlier investigators frequently attributed to lack of vitamins, nutritional disorders which were in reality the result of deficiency or ill-balance of the mineral constituents of the diet. The common home-produced feeding-stuffs (grains, grain offals, green crops, hay, roots, and dairy by-products) are satisfactory sources of vitamins, and Orr concludes that farm animals are not likely to suffer from deficiency troubles of any kind when they are receiving *properly balanced* rations containing such feeding-stuffs.

On account of the richness of cod-liver oil in respect of vitamin A, it is but natural that arguments should have been put forward in favour of its wider use in the feeding of all classes of farm stock. Golding and his co-workers (J. Golding, " Vitamins in Agriculture," *Bulletin* xxxii, Univ. Coll., Reading, 1923) state that pigs kept in confinement, without access to green fodder, benefit greatly in growth and general condition if given daily doses of cod-liver oil. The requirements of large pigs are satisfied by daily additions of one to two ounces to the diet, and it is claimed that such doses do not in any way affect the flavour of the pork or fat. The Aberdeen workers, however, deprecate the use of cod-liver oil simply and solely as a source of vitamin A, on the grounds that the pig's requirements for this growth factor are inconsiderable and can readily be supplied by the use of the ordinary farm feeding-stuffs. They state further that the incautious administration of fishy oils to pigs may cause a taint to appear in the cured bacon, even in cases where the fishy flavour is not detectable in the fresh pork (Orr and Crichton, *Scottish Jour. of Agric.*, vi, 279, 1923).

Promising results have been secured at Reading in connection with the use of cod-liver oil for dairy cows (Drummond, Channon, Coward, Golding, Mackintosh, and Zilva, *Jour. Agric. Sci.*, xiii, 144, 1923 and xiv, 531, 1924). The presence of vitamin A in cow's milk is shown to be entirely dependent on its presence in the diet of the animal. Cows stalled in the winter and fed on ordinary winter rations of seeds hay, roots, and concentrates may yield milk with only one-tenth the growth-promoting factor found in the milk of grass-fed cows. The addition of small doses of cod-liver oil to such deficient rations induces a sharp rise in the vitamin A value of the milk fat of the cows. No such rise is noted when oils deficient in this growth factor are given. The administration of cod-liver oil in doses from one to eight ounces per day to milking cows appears to cause no fishy taint in the milk or butter fat.

A continuance of these investigations into the effect of vitamin-rich foods on the nutritive value of the milk of the cows receiving them is obviously desirable. The writer ventures the opinion that in this direction the results of vitamin research will find their most serviceable application to the problems of animal husbandry. A note of warning is necessary, however, since the initial work carried out at Reading indicates that excessive administration of cod-liver oil to milking cows may result in a distinct lowering of the percentage of butter fat in the milk.

Metabolism of Growth and Maintenance.—Considerable advances have been made in the knowledge of this subject from the point of view of energetics during the last few years, notably in the publications proceeding from the Institute of Animal Nutrition at Cambridge. In 1920 a calorimeter for use with large animals was completed (J. W. Capstick, *Jour. Agric. Sci.*, xi, 408, 1921). In 1922 J. W. Capstick and T. B. Wood published an account of experiments in which measurements were made of the heat evolution of a fasting hog at various stages up to a maximum of six days and at various temperatures between 24° C. and 10° C. (*Proc. Roy. Soc.*, B. vol. 94, 35, 1922). It was concluded that, from about the twelfth hour after feeding onwards, the excess of the total resting metabolism above the basal metabolism fell off according to the simple exponential law $H = e^{c-kt}$ (where *c* and *k* are constants). In other words, the excess of the actual over the basal metabolism appeared to depend only on the time which had elapsed since the last meal and was proportional to the amount of metabolisable substance still unchanged. The same authors showed that the critical temperature of the pig under experiment (weight = 300 lb.) was about 21° C. At this temperature the basal metabolism possessed a minimum value of 2,160 Cals. per day. As the temperature of the surroundings fell below the critical temperature, the basal metabolism increased at the rate of about four per cent. per degree Centigrade (*Jour. Agric. Sci.*, xii, 257, 1922).

In 1923 T. Deighton, working with the same instrument, showed that the basal metabolism per square metre of a young hog was not constant over the period of youth, but displayed a maximum when the animal attained the age of four months (*Proc. Roy. Soc.*, B. vol. 95, 340, 1923). From his direct measurements, Deighton obtained a curve which resembled in a striking manner that obtained by E. F. Du Bois by statistical methods for the metabolism of the human subject (*Arch. Internal Medicine*, xvii, 887, 1916). From this he drew important conclusions as to the rationing of this (Large White) breed, showing that the maintenance requirement of such growing pigs exceeds that dictated from a mere consideration of the surface law. Deighton's results enabled him to account for the difficulty experienced in preparing this breed of pig for the market at 60–70 lb. live weight. His conclusions have been tested and confirmed by feeding and slaughter experiments on the University Farm, Cambridge, and the results of this work have been summarised in a series of lectures delivered on this and kindred subjects by Prof. T. B. Wood at the University of London in March 1925 (not published at the time of writing).

The Scientific Rationing of Farm Animals.—In his recently published textbook on *Animal Nutrition* (W. B. Clive, London, 1924), Prof. T. B. Wood has achieved a distinct advance in regard to the application of scientific principles to the rationing of farm animals. After noting the weaknesses of the old feeding-standard systems of Thaer, Wolff, Lehmann, and Kellner (viz. their lack of elasticity and the difficulty of modifying them to meet varying requirements), Prof. Wood proceeds to elaborate a system whereby the ration required to produce any desired rate of live-weight increase for an animal of any given weight, age, and condition can be read off at sight.

Starting from certain experimental data accumulated by Armsby in America, it was possible to calculate the weight of starch equivalent required to produce 1 lb. of live-weight increase in cattle of various weights and ages and in varying conditions of fatness. These particulars are given in the accompanying table :

Age of animal in years.	Condition.	Lbs. of S.E. for 1 lb. of live-weight increase.
About 1½ . . .	Forward stores.	2·00
„ 2 . . .	Stores.	2·25
„ 2¼ . . .	Stores.	2·50
„ 2½ . . .	Half fat.	3·00
„ 2¾ . . .	Nearly fat.	4·00

From these figures it is an easy matter to calculate a production ration which will produce any desired rate of live-weight increase within the capacity of the animal. To this, of course, must be added the ration requisite for maintenance, the latter requirement being related to the weight of the animal. The maintenance requirements of animals of varying weight have been formulated from data referring to a 1,000 lb. ox by the application of Rubner's surface law. Examples of these figures, together with the capacity of consumption of animals of varying weights, are given below :

Live Weight. Cwt.	Maintenance ration in lb. starch equiv.	Appetite of animal in lb. dry matter per day.
7	5·0	19·0
8	5·5	20·5
9	6·0	22·0
10	6·5	23·5
11	7·0	25·0
12	7·4	26·5

As an illustration of the method of applying these principles, an example may be cited where it is desired to produce 2 lb. live weight increase per day in the case of a forward store 18 months old and weight 8 cwt. The ration would be computed thus :

Maintenance ration for 8 cwt. animal . .	**5·5 lb. starch equiv.**
Production ration for 2 lb. increase per day .	**4·0 „ „ „**
Total ration . .	**9·5 „ „ „**

The problem then becomes one of adjusting the mixture of feeding-stuffs so that 9·5 lb. of starch equivalent is supplied in a ration within the capacity of the animal's appetite, which is about 20·5 lb. of dry matter per day.

The method is equally applicable to sheep and pigs, and has been used successfully for working out rations for milk production. The production ration per gallon of milk of average quality is 2·25 lb. of starch equivalent, though this figure must be increased if the milk contains more than 3·5 per cent. of butter fat.

Owing to the absence of information in regard to the maintenance requirements of young animals, Prof. Wood's system cannot, as yet, be employed successfully for the calculation of rations in such cases. To quote Prof. Wood: "The feeding of such very young animals must for the present remain an art which must be acquired by practical experience rather than a science based on proved principles."

The Influence of Cooking on the Nutritive Value of Feeding Stuffs.—It may seem strange that doubt should still exist in regard to the effect of preliminary cooking on the nutritive value of a feeding-stuff, yet a survey of the nutritional literature relative to this question reveals considerable uncertainty as to whether the cooking of a feeding-stuff prior to its being fed to animals leads to any material improvement in feeding value.

In view of the common practice among pig-feeders of cooking maize for swine, the results of recent investigations into the influence of cooking on the nutritive value of this important feeding-stuff are of interest (H. E. Woodman, *Jour. Agric. Sci.*, xv, 1, 1925). Digestion trials with Large White hogs were carried out with the object of instituting a comparison between dry-fed, soaked, cooked, and flaked maize. The digestion coefficients obtained in these experiments are summarised in the accompanying table:

—	Dry-fed Maize per cent.	Soaked Maize per cent.	Cooked Maize per cent.	Flaked Maize per cent.
Dry matter	85·9	86·9	88·1	95·2
Organic matter	87·1	87·8	89·0	95·4
Protein	78·4	80·1	86·1	95·5
Oil	63·5	60·5	63·6	44·8
Carbohydrate	91·5	92·0	92·4	97·1
Fibre	23·1	35·3	22·6	30·5

The above results bring out clearly the effect of preliminary treatment on the digestibility of maize. Thorough soaking raises the digestion coefficient of the maize dry matter from 85·9 to 86·9 per cent.; efficient cooking leads merely to a further small rise to 88·1 per cent. The conclusion is therefore warranted that the cooking of maize for swine is an uneconomical procedure, the gain in nutritive value not being such as to compensate for the trouble and expense of cooking and the attendant risk of the wet material turning sour if kept too long. In spite of the satisfactory results obtained for dry-fed maize, the feeding of the dry crushed grain is not recommended, since in practice it leads to a large expenditure of energy by the animal during mastication, a circumstance which results in a corresponding diminution of the productive energy of the feeding-stuff. This difficulty is overcome when the grain is soaked thoroughly prior to feeding.

The increase of protein digestibility from 78·4 to 86·1 per cent. as a result of cooking is noteworthy, since previous investigators, using the artificial digestion method of Stutzer, have concluded that cooking depresses the protein digestion coefficient of a feeding-stuff. The inconsiderable improvement in the digestibility of the starchy constituent of maize brought about by cooking leads to the conclusions that the cellulose coatings of the starch cells are easily removed during digestion, and further, that although cooking may render the starch more *easy* of digestion, yet, when dealing with animals possessing extensive digestive tracts, this does not necessarily imply a more *complete* digestion of the constituent in question.

The high value obtained for the digestion coefficient of the dry matter of flaked maize is of special interest in view of the efforts of certain commercial enterprises to popularise this form of maize with the stock-feeder. In the manufacture of flaked maize, the grain is submitted to the several processes of screening, steaming, rolling, and drying. The resulting product consists of crisp yellow flakes composed almost entirely of protein and soluble starch. It is probable that the high degree of digestibility of these constituents is to be attributed to their presence in the feeding-stuff in a form easily accessible to digestive ferments in the alimentary tract.

In further experiments (H. E. Woodman, *Jour. Min. Agric.*, xxxi, March 1925) it was demonstrated that the cooking of barley for pigs does not enhance the nutritive value beyond that possessed by soaked barley.

ARTICLES

WHEN CERTAIN MATHEMATICAL FORMULAS BECAME TRUE

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THE fact that certain mathematical formulas in their modern form were not always true may be illustrated by a very useful formula for the determination of the area of a plane triangle, which is now commonly written as follows :

$$F = \frac{ab \sin C}{2}$$

where *a*, *b* represent the lengths of two sides of the triangle, and C is the included angle. It is obvious that this formula does not represent the area of such a triangle unless $\sin 90° = 1$. For instance, in the earliest logarithmic table published by J. Napier (1550–1617), which includes a table of sines, $\sin 90° = 10{,}000{,}000$, and hence the given formula represents the area of a triangle multiplied by ten million if this well-known table is used in the calculation to find the value of sin C. Similar remarks apply to most of the earlier tables of sines, as well as to some of the later ones. Hence one may at once conclude that the given formula in its modern form could not have been generally regarded as true until after the time of Napier, and it is an interesting fact that it appeared as early as ten years after the death of Napier in the trigonometry of Snellius in the form of a proportion, as follows :

$$1 : \sin C = ab : 2F$$

Two opposite tendencies can be clearly seen in the development of our modern definitions of the trigonometric functions. One of these was to assign to these functions such large numerical values as to avoid to a considerable extent (if not entirely) the use of fractions, while the other was to simplify the formulas by assuming that $\sin 90° = 1$ and defining the trigonometric functions accordingly. The former of these tendencies was natural at the time when the use of fractions was not well understood by some of those who made calculations by means of the tables of the trigonometric functions, and it became very pronounced during the fifteenth and sixteenth centuries, when very extensive tables of these functions were computed by Puerbach, Regiomontanus, Copernicus, Rhæticus, and many others. In fact, it appeared at this time as if it would gain the mastery, but fortunately the growing interest in the development of the theory of trigonometry soon thereafter turned the tide in the opposite direction. The Swiss mathematician, J. Bürgi (1552–1632), is said to have computed a table of sines, now lost, in which the advantages of letting sin 90° = 1 were explicitly recognised.

The very important law of sines in trigonometry was clearly not affected by the different values which were assigned to sin 90° by various writers, and hence the history of the long struggle for the mastery along this line does not throw any light on the date when this law appeared in its modern form. On the other hand, the formula which expresses the law of cosines in its modern form was clearly affected by the outcome of this struggle as well as by the introduction of negative numbers. For the latter reason the Arabs, who did much towards the development of trigonometry but did not use negative numbers, could not have fully understood the law of cosines in its modern form, but they proved the law of sines both for the plane and for the spherical triangle as early as about A.D. 1000, and they used what is nearly equivalent to the law of cosines at about the same time. In fact, they did not have a special name for cosine, although the Indian mathematicians employed such a name at an earlier date.

From what precedes and from the history of negative numbers it results that the formula expressing the law of cosines in its modern form could not have been generally understood before the seventeenth century, and that some of the later mathematicians could not have accepted it as always true. Hence one of the most useful formulas in our modern courses in elementary trigonometry did not become true in the sense in which the symbols involved therein were commonly understood until after the sixteenth century. Such inter-relations of historical facts tend to make the study of the history of science of great value as an educational subject, since this study demands more reasoning and less pure memory work as one enters more deeply into the subject, and it is one of the beautiful chapters of the history of the human mind. Cf. E. Picard, *Bulletin des Sciences Mathématiques*, volume 59 (1925), page 130.

Two of the fundamental trigonometric formulas which have been considered briefly appeared at about the time when the symbols involved therein began to be commonly defined in such a way as to make these formulas true. It may be of interest to consider here also two fundamental formulas which were practically in use long before the time when their modern significance was fully understood. In fact, this significance is in disaccord with the facts according to the standpoint of those who first employed rules which are equivalent to these formulas. The first of these formulas represents the two roots of the general quadratic algebraic equation. It is well known that the Greeks (in particular, Heron and Diophantus) used rules which are separately equivalent to such a formula, but they could employ such a rule only when it led to a positive root, since they used neither negative nor imaginary roots of an algebraic equation.

The formula representing the two roots of a general quadratic equation was practically used in special cases for more than a thousand years before it became true that such an equation always has roots, in view of the limitations as regards the number system to which the roots were assumed to belong. Hence we have here a formula which was only partially true for many years after it began to be used in special cases. Somewhat similar remarks apply to the so-called Cardan formula, probably due to Ferro, for the solution of the general cubic equation. In this case more than two hundred years elapsed from the time this formula was first published in 1545 until it was clearly recognised by D'Alembert that it always represents the three roots of the equation in question. Not only did the early users of this formula fail to recognise that it represents the three roots, but they failed to see that it represents any root except in the special case when the cubic has one positive and two imaginary roots. In fact, as long as negative and imaginary roots were excluded it did not necessarily represent any root.

It is obviously desirable to develop the history of science in general and the history of mathematics in particular with as much emphasis as possible on the employment of reason. It is only in this way that the subject becomes a ferment in the mind of the student, which serves not only to encourage a continuation of his efforts, but also a proper co-ordination of the facts already acquired. It is hoped that the point of view expressed above may serve to exhibit a useful additional instance of the possible emphasis on reason in the study of the history of mathematics.

OBSERVATIONS OF SYSTEMATIC MOVEMENTS WITHIN THE SUN

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THE purpose of the following article is to review briefly the observations which give evidence of systematic movements which are taking place in the Sun's atmosphere, either of a cyclic or non-cyclic character. The subject is one of increasing interest with the advance of stellar physics.

Observations of movements in the Sun are made with the telescope used (1) directly by the observer, or modified, firstly, as a photo-heliograph for recording the photosphere with its granulation, sunspots, and faculæ, and, secondly, as the coronagraph of eclipse expeditions for photographing the Sun's corona; (2) with the spectroscope, which renders the chromosphere and the prominences (when present) always accessible and provides a means of measuring radial motions of approach or recession through the Doppler effect, whilst the determination of magnetic polarity and field strength in sunspots has been made possible by the observation of the Zeeman effect; (3) with the spectroheliograph, which produces photographic images both of the chromosphere and prominences, and of the Sun's surface in monochromatic light of calcium, hydrogen, or iron, with the added power of reaching different levels at which the elements occur; (4) with the *spectro-enregistreur des vitesses*, or velocity recorder, which delineates the areas on the Sun's surface where ascending or descending movements of gases are taking place in the higher levels of the atmosphere.

Two keen observers of sunspots, Carrington in England and Spörer on the Continent, brought two important facts to light in the middle of the last century. The first of these discoveries was the change of latitude of the spot zones during the progress of the eleven-year cycle, the period of which had been announced by Schwabe in 1843. This cyclical change of latitude is best shown in a diagrammatic form, as published by Maunder from the Greenwich measures. A diagram including the most recent observations, with comparative curves of spot areas and of the variation of the diurnal range of magnetic declination, has been exhibited in the Science section at Wembley. The nature of this cyclical movement of the zones is as follows: The spots of a new cycle begin to appear intermittently in latitudes from 30° to 40° on both sides of the Sun's equator. With increase in the number and size of spots, the zones commence to spread equatorwards, and by the time of maximum (occurring on the average about four and a half years after the previous minimum) the spots are distributed in broad zones centring about latitude 15° north and south. The centres of the zones continue to approach each other until, within a year of the minimum, they are found mainly in equatorial regions about 8° latitude. At this time, small spots begin to appear again in latitudes 30°–40° as heralds of the new cycle, which becomes well established as the equatorial spots of the old cycle die out. This equatorward progression of the spot centres does not appear to be shared by the movements of individual spots, which have, on the average, a small random motion in latitude, but no consistent movement towards the equator of a measurable amount. A similar progression in latitude during the eleven-year cycle is shown by the bulk of the faculæ[1] and the calcium flocculi which invariably accompany and survive spot disturbances. The prominences which rise from the chromosphere into high levels of the Sun's atmosphere show a compound distribution.[2] They are found chiefly in two belts in each hemisphere, north and south; the inner two of the four belts coincide roughly with the spot zones and follow them in their equatorward march. The outer zones after spot maximum are found mid-way between the equator and the poles, where they persist without much change of latitude, though with cyclical change of frequency, until the following maximum is approaching, when they move rapidly to the poles and disappear. After a short lapse of time they reappear again in mid-latitudes, and the changes are repeated. From an examination of extensive data collected at the Yerkes Observatory, Lee[3] finds that only about 6 per cent. of prominences in the spot zones suggest any immediate connection with spots; the similarity in the movement of the zones producing these two phenomena, at different levels in the solar atmosphere, is significant.

The second fact of importance noted by Carrington and Spörer was that spots at different latitudes gave, on the average, different values for the Sun's rotation period. The shortest period was found to be given by the equatorial spots with accelerating rate of increase of period towards the outer zones.

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[1] *Monthly Notices of R.A.S.*, **84**, 96, 1923.

[2] *Results of Prominence Observations*, by J. and M. A. Evershed, 1917.

[3] *Astrophysical Journal*, **45**, 206, 1917.

The usual expression adopted for the sidereal diurnal motion due to the Sun's rotation is of the form $\xi = a - b \sin^2 \phi$, where a is the diurnal motion at the equator and ϕ is the latitude. A recent determination[1] of the Sun's rotation period made at the Royal Observatory, Greenwich, from 450 spots of regular outline lasting for at least twenty-five days, gives $\xi = 14^\circ{\cdot}37 - 2^\circ{\cdot}60 \sin^2 \phi$.

The equatorial acceleration, as it has been usually called, or polar retardation, has been fully confirmed and amplified by spectroscopic measurements. The light from symmetrical points on the Sun's approaching eastern limb and receding western limb is brought on to the slit of the spectrograph by means of prisms. The Doppler effect resulting from the Sun's rotation is thus doubled and rendered a measurable differential quantity. Measures can be made from the equator and beyond the spot zones to the polar regions, but necessarily with probable errors increasing with the latitude. W. S. Adams, to mention one of the chief investigators of this method, made an important contribution in his *Investigations of the Rotation Period of the Sun*, published in 1911. Observations were not confined to one line in the spectrum, but were extended to those of various elements—hydrogen, calcium, iron, lanthanum, cyanogen, and manganese. Moreover, by a choice of lines, based on their relative intensities, a distinction could be made between successive levels of the same element, the weaker lines originating from the lower levels of the solar atmosphere. The following table provides a comparison between results derived from various sources and by different methods.

DIURNAL SIDEREAL MOTION AT LATITUDE 15°

Source.	Authority.	Formula.	Motion.
Sunspots . . .	Carrington, Spörer, Maunder, Greenwich	$14^\circ{\cdot}37 - 2^\circ{\cdot}60 \sin^2 \phi$ (Greenwich)	14°·2
Reversing layer .	Adams	$14^\circ{\cdot}54 - 3^\circ{\cdot}50 \sin^2 \phi$	14°·3
Faculæ . . .	Stratonoff, Chevalier, Greenwich	$14^\circ{\cdot}54 - 2^\circ{\cdot}81 \sin^2 \phi$ (Greenwich)	14°·3
Calcium flocculi .	Hale & Fox, Fox	$14^\circ{\cdot}56 - 2^\circ{\cdot}98 \sin^2 \phi$ (Fox)	14°·3
Calcium line λ 4227 .	Adams	$14^\circ{\cdot}9 - 2^\circ{\cdot}4 \sin^2 \phi$	14°·8
Hydrogen line, Hα .	Adams	$15^\circ{\cdot}0 - 1^\circ{\cdot}4 \sin^2 \phi$	14°·9
Calcium line, K_2 .	St. John	—	15°·5

From several considerations, the order of the phenomena in the table is also that of ascending level in the solar atmosphere.

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[1] *Monthly Notices of R.A.S.*, 85, 551, 1925.

It will be seen that besides the well-pronounced decrease of angular velocity with increasing distance from the Sun's equator, as illustrated by the third column, there is also evidence of an increase of angular velocity from low to high levels. This increase of velocity with height appears if we consider spectroscopic data alone, as in Evershed's paper in the *Monthly Notices* for May 1925. He finds that the prominences which are located in very high levels give the greatest mean angular motion observed, and concludes that the shortest period of rotation, about twenty-one days, apparently occurs entirely outside the limits of the chromosphere. Attempts have been made during total solar eclipses to measure spectroscopically the rotation of the Sun's corona, but so far, owing largely to the faintness of the coronal spectrum, these have proved unsuccessful. From the measurement of a portion of the corona obtained on plates at two different places in the zone of totality, the Sproul observers of the eclipse of September 10, 1923, find evidence[1] of groups of streamers, originating in comparatively low solar latitudes, to be rotating with the Sun.

Two or three further remarks follow from the preceding table. There are indications in the third column that the latitude term becomes smaller with increase of level, and this is further supported by St. John's observations[2] of the K_2 line of calcium, which gave practically a constant angular velocity for the latitudes of observations. The second point of interest lies in the differences of the spectroscopic determinations made by different observers, and by the same observer at different epochs. The differences are greater than would be expected from the internal agreement of the measures of the separate determinations, and Halm[3] has postulated a variation in the Sun's general rotation period. The extensive observations of Adams do not confirm this, however, but at the same time he points out the need of extended observations, inasmuch as a limited series may be seriously vitiated by considerable radial proper motions, which are observed at times in the vicinity of spot disturbances, in or near the level of the reversing layer. No doubt the question of variability of rotation period will be settled by the series of spectroscopic determinations of the equatorial rotation which are being made at Mount Wilson. The mean value for the years 1914–1918 is 1·936 km./sec., and for the last six years 1·903 km./sec. The importance of carrying on such a series of observations for two or four multiples of the eleven-year spot cycle is enhanced by Hale's discovery of the alternation of the magnetic polarities of spots in successive spot cycles. In passing it may be mentioned that a comparison [1] of the rotation periods derived from spots for the four cycles, 1878–1923, establishes no evidence, either for a variation of rotation period with successive cycles or any measurable difference in behaviour between the northern and the southern hemispheres. The observations, however, are necessarily restricted in latitude from the equator to ± 30°, and are sparse near minimum.

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[1] *Astrophysical Journal*, **61**, 73, 1925.

[2] *Ibid.*, **32**, 80, 1910.

[3] *Astronomische Nachrichten*, **173**, 294, 1907.

The variation of the angular velocity of rotation with latitude and the evidences for the vortex nature of sunspots suggests a search for a systematic drift of spots in latitude quite apart from the equatorward progression of the spot zones. The possible existence of small drifts had been shown by Carrington's observations and those discussed in a *Determination of the Position of the Sun's Axis* " (1912) by the Astronomer Royal and E. W. Maunder, but the evidence was not decisive. Recently, the movements of all long-lived spots have been examined from 1879 to 1923, and it was found that, whilst the random motion in latitude is about 1° per sidereal rotation of the Sun, there is no evidence of a systematic drift of as much as 0°·1 in the same interval.[2] On the other hand, the faculæ, which are considered to be at a higher level than the spots, give a poleward drift increasing with the latitude and reaching nearly 1½° per sidereal rotation in latitudes 20°–30°. Further evidence of this poleward drift given by the faculæ is very desirable, especially from the calcium flocculi, with which there is a close relationship.

The existence of considerable differential motions of sunspots in longitude has long been recognised, either by direct observation or indirectly by the widely different rotation periods which are frequently deduced from different spots in the same latitude. Some of these motions are of a systematic nature, and are chiefly noticeable during the early development of a " bipolar " group or " stream " of spots, which is the predominating type of spot disturbances. These movements of a characteristic nature have been put in a definitive form.[3] It is found that in the first two days of its life the average leader spot of a bipolar group moves rapidly forward in longitude at the rate of about 1° a day. In the next two days the rate has diminished to about 0°·5 per day, and it continues to diminish until about the fifteenth day, when the movement of the spot is the same as that of the mean diurnal motion of the Sun's rotation corresponding to its latitude ; by about the twentieth day, it is moving slowly backwards at a daily rate of about $0^\circ\cdot5$. Meanwhile, corresponding changes are taking place in the size of the spot, which increases rapidly after its formation, reaches a maximum about the tenth day, and then slowly declines. On the contrary, the following spot of the group, which is invariably of much shorter duration, moves consistently slower than the mean velocity appropriate to its latitude, particularly in the first three days of its existence. These systematic movements of the chief components of a typical group of spots suggest a search for a correlation with motion in the line of sight or the variation of the strength of the magnetic fields in the two spots.

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[1] *Monthly Notices of R.A.S.*, 85, 551, 1925.
[2] *Ibid.*, 85, 190, 1924.
[3] *Ibid.*, 85, 553, 1925.

A systematic motion of the gases within sunspots was announced by Evershed in 1909 from his spectroscopic observations. When the spectra of both sides of the penumbra and the umbra of a spot can be photographed when it is within a little distance of the Sun's east or west limbs, Doppler effects are observed which can be explained by a horizontal flow of the gases of the reversing layer directed radially outwards from the umbra and ceasing abruptly at the limits of the penumbra. The gases of the higher chromosphere do not participate in this movement, but, on the contrary, move radially inwards. These observations, begun by Evershed, have been extended with valuable results by St. John with the powerful instruments of the Mount Wilson Observatory.[1] In all, 506 lines of the spectrum have been studied, which include 27 elements; lines known to originate in the higher levels of the chromosphere, such as H, K, and Hα; enhanced lines, and lines belonging to different pressure groups; and 193 iron lines of varying intensities, which were subsequently found to be a valuable criterion of level, the weaker lines originating from the lower levels. St. John's results, summarised in a very suggestive diagram, indicate the radial velocity-system in the upper section of a solar vortex. The vapours of iron and some heavier elements flow horizontally outwards from the spots with velocities[2] of 1 km./sec., decreasing with ascent of level (as shown by line intensity) up to the region of the reversing layer. Then occurs a level of velocity-inversion as evidenced by certain of the magnesium lines, aluminium lines, and the calcium line, λ4227. Above this, in the chromosphere, the lines due to Hδ, D_1D_2, Mg b_1b_2, Hγ, H_2K_2, Hα, and H_3K_3 show velocities increasing with height up to 1·9 km./sec., horizontally towards the spots in the order mentioned. St. John, however, points out that for several reasons these movements do not of themselves constitute a complete vortex system; the actual vortex in which the magnetic field originates is apparently deep-seated, the region of the outflow of the heavier elements into the lower reversing layer being a portion of the upper part of it. This will be referred to later.

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[1] *Astrophysical Journal*, 37, 322, 1913, and 60, 39, 1924.

[2] These are average velocities observed at the outer edge of the penumbra. Apparently the motions are accelerated outwards from the centre of the spot to the outer boundary of the penumbra. The greatest outward velocity observed by St. John in the case of any line was 2·2 km./sec.

As additional data bearing on the structure of this upper vortex, observations of radial velocities can be made when the spot is near the centre of the Sun's disc. St. John has already made a number of these observations and finds that there is usually a downward movement of calcium vapour over the umbræ of spots varying in velocity from 0·7 to 2·2 km./sec. Evershed recently recorded a large motion of this kind of the order 3–4 km./sec. radially downwards.[1] A new survey of the radial velocities in spots is being undertaken by the Mount Wilson observers.

The regions immediately surrounding sunspots will now be considered. Every sunspot disturbance is accompanied by faculæ, calcium flocculi, and hydrogen flocculi, which make their appearance with the spots, possibly a few hours before, increase in extent with the development of the spots, and remain visible after their disappearance often for a considerable time. Butler, from the Cambridge collection of spectroheliograms, has traced the growth of the calcium flocculi from their first appearance with the spots to their final merging into the general chromospheric réseau of the Sun's surface.[2] The distinction between the faculæ and the calcium flocculi is not very clear: the former are shown usually only near the Sun's limbs in integrated light from the photosphere, the latter can be followed right across the disc in monochromatic light of the H and K lines of calcium. Presumably the faculæ form the base from which the flocculi arise, but there seems to be no evidence of convection between the two.

By using different parts of the doubly reversed H and K lines, Hale and Deslandres independently showed that the spectroheliograph is able to record the calcium flocculi at different levels, corresponding approximately to the levels of the reversing layer, the chromosphere, and the prominences. The portions of the H and K lines are known as H_1K_1, H_2K_2, and H_3K_3 respectively. By a similar use of the broad Hα line, records of three successive layers of hydrogen vapour can be obtained.

The spectroheliograms taken of the middle levels of calcium have been used by Hale and Fox for measuring the Sun's rotation in the same way as sunspots. Fox[1] has also investigated differential motions of the calcium flocculi, and finds that for the period 1903–8 they have movements which are anti-cyclonic about single spots, cyclonic about the preceding members of bipolar spots, and anti-cyclonic about following members. Spectroscopic observations of radial motions indicate, on the other hand, that the penumbral or extra-penumbral vortex is not developed around every spot.[2] In contrast to the calcium spectroheliograms, those taken in the intermediate levels of H*a* are extremely suggestive in appearance of vortical motion, which at the time of Hale's discovery of magnetic fields in spots was regarded with great interest. Hale now states, however, that about 75 per cent. of the hydrogen vortices associated with single or preceding spots in *both* hemispheres conform in direction of whirl with terrestrial cyclones, whereas preceding spots are observed to have opposite polarities on opposite sides of the equator. There is also no evidence of a change of direction of whirl, figured by the hydrogen spectroheliograms, with the observed alternation of magnetic polarities at the spot minima of 1913 and 1923. This is one reason for regarding the radial velocity system described on a previous page as a secondary effect, overlying the main vortex which produces the magnetic field.

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[1] *The Observatory*, June 1925, 168.

[2] *Monthly Notices of R.A.S.*, **84**, 148, 1924.

A productive field of research has been opened by the use of Deslandres's *spectro-enregistreur des vitesses*, which is an adapted form of spectroheliograph with a wide second slit to admit a small portion of the adjacent spectrum. Successive chords of the Sun's disc in K_2 light, for instance, can be photographed by a series of discontinuous movements, and displacements of the line due to Doppler effects are thereby recorded over the Sun's disc wherever they may occur. With this instrument, Deslandres[3] has studied the dark filaments and alignments which are such a characteristic feature of the high-level calcium and hydrogen spectroheliograms, taken respectively in the light of K_3 and the middle of the H*a* line. He finds that the filaments are regions of ascent in contrast to the bright areas of flocculi, which are usually descending. Their close relationship with the prominences[4] seen in profile at the Sun's limbs suggests that they are the same phenomenon seen projected on the disc. Further systematic study of these filaments is being carried out by Deslandres and his assistant, d'Azumbuja, at Meudon, by Royds at Kodaikanal, and elsewhere.

St. John has specially studied the behaviour of the K_2 and

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[1] *Publication of the Yerkes Observatory*, vol. iii, pt. iii, 1921.

[2] *Astrophysical Journal*, 34, 139, 1911.

[3] *Annals of the Meudon Observatory*, vol. iv.

[4] *Astrophysical Journal*, 45, 206, 1917.

K_3 lines over the disc with a section spectrograph designed on the principle of the velocity recorder. With it, exposures can be made rapidly of successive points on the disc or successive exposures of the same point, and the measurement of the displacements due to the Doppler effect are made absolute by a comparison in the same field with two solar standard iron lines. In this manner, from a large number of measures, he has compared the wave lengths of the absorbing K_3 line and the emission K_2 line with that of the arc at various parts of the Sun's disc—over undisturbed areas, circumfacular regions, flocculi, and spots. Briefly, he finds :

(1) That over the general surface of the Sun the calcium vapour producing the absorption line, K_3, has a descending motion of 1·14 km./sec., while that due to the bright emission, K_2, is ascending at 1·97 km./sec.[1] These are very definite results obtained from a large number of observations. More recently, St. John has extended his research on vertical currents in undisturbed regions of the Sun's disc by a comparison of the wave-lengths of more than three hundred iron lines in the solar spectrum and the vacuum arc. The strong lines (*i.e.* high-level lines) of iron give a mean downward radial velocity of 0·3 km./sec., whilst at the lowest levels possible to investigation at present the motion is 0·3 km./sec. upwards. A significant fact is that these radial convection currents are remarkably constant at any given level.[2]

(2) Immediately over flocculi surrounding spots, the emitting vapour, due to K_2, shows almost stationary conditions, whilst the absorbing vapour, the source of K_3, is descending with the same mean velocity as over the general surface, *i.e.* 1·14 km./sec.

(3) Over circumfloccular regions there appears to be no evidence of a local system of circulation involving the flocculi and their immediate surroundings, although, as already shown, there is a local system in connection with the spots in which emitting calcium vapour, presumably rising around the flocculi, flows across the penumbra and is drawn downwards into the umbra.

It should be mentioned that Deslandres, on the contrary, finds evidence of a circulatory system between the circumfacular regions and the faculæ. Further systematic observations will no doubt remove the discrepancy between these two observers on this point. With increasing power of new spectrographs and telescopes it should be possible to make measures of the small, bright granules and their darker interspaces which make up the general granulation of the Sun's surface in integrated light, and the chromospheric réseau of the calcium spectroheliograms. A determination of any radial motions of a constant character which the integral portions of the Sun's surface may possess will be of great importance. Attempts in the past have been made by Hansky and Chevalier to study the transverse motions of the granules, but nothing of a systematic nature was discovered, perhaps owing to the inherent difficulties of observation.

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[1] *Astrophysical Journal*, **32**, 79, 1910.

[2] *Monthly Notices of R.A.S.*, **84**, 93, 1923, and *Astrophysical Journal*, **60**, 39, 1924.

The possibility of finding currents parallel to the Sun's surface at the highest levels of the solar atmosphere has not been overlooked by observers. Slocum[1] has examined the prominence data at Yerkes for any preference of direction which might be shown by the serrated top of the chromosphere and the forms of prominences. The evidence from the former is negative, and the prominences, though showing tendencies for preferential directions varying with the latitude, give no clear indication of general circulatory currents. St. John[2] had tested the matter in another way by measuring the mean wavelengths of the intermediate and high-level calcium lines (K_2 and K_3) at points in close proximity to the limb in polar regions and in equatorial regions. His measures showed the absence of any such currents of appreciable velocity.

Recently, Pettit has published a thesis on the "Forms and Motions of the Solar Prominences," based on collected data from 1892 to 1920. The nature and origin of a force or forces expelling the prominences at great velocities (observed up to 400 km./sec.) are considered quantitatively. The vertical motions to be explained are nearly always uniform, but affected by sudden increases as though an impulse had been given from time to time. Measurements of only six prominences connected with sunspots were available, but in these cases the motions of the knots and streamers were directed to the spot.

Observations of movements within the corona are necessarily scanty and difficult. The cyclical change of shape in the eleven-year spot period is of a most conspicuous character, as is well known. At spot maximum, the general distribution of the corona is roughly concentric with the Sun's disc ; at minimum, there are short, well-defined brush-like plumes at the Sun's poles, and broad streamers extend from the equatorial regions ; at other phases of the spot cycle, the corona is intermediate between these two types. Each corona belonging to the same phase of different cycles has, however, its own individuality. W. J. S. Lockyer[3] has found a relationship between the various forms of the corona and the active zones of prominences. There is also evidence that the local arrangements occasionally observed of the lower corona in a series of arches are related sometimes to sunspot disturbances and on other occasions to prominences. Attempts have been made at several eclipses to measure the radial movements of the arches by comparison with plates taken at different stations in the zone of totality. The deduced radial velocities outwards from the sun are variable, but of the order of 20 km./sec.—a small velocity compared with those frequently observed for the prominences.

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[1] *Astrophysical Journal*, 37, 357, 1913.

[2] *Ibid.*, 32, 80, 1910.

[3] *Monthly Notices of R.A.S.*, 82, 324, 1922.

The observed movements in the Sun's atmosphere have a far-reaching application when interpreted both in the light of the theoretical researches of Russell, R. H. Fowler, E. A. Milne, and others on the constitution of the reversing layer and chromosphere, and of the observational data on pressure at various solar levels obtained recently by St. John and Babcock. The study of high-dispersion stellar spectrograms shows that in bright stars such as Sirius, Procyon, and Arcturus there is a relative displacement of arc and enhanced lines. The hypothesis is advanced in a paper [1] by St. John and W. S. Adams that this displacement is due to differences in radial velocity of gases in the atmospheres of these stars, the lines produced at the higher levels showing, as in the Sun, a prevailing downward motion. This gives strong support to an hypothesis advanced by Campbell in 1914 that the K— term in B-type stars is due, at least in part, to convection currents in stellar atmospheres.

The observational data for studying the Sun's atmosphere, possible to the range of our various instruments, will receive a considerable addition within the coming decade. During the last year, solar activity in its various manifestations has been rising in accordance with the eleven-year period after a minimum dating about the middle of 1923. Through the increasing cooperation of observatories in widely different parts of the world, practically a continuous daily record is kept of the changes occurring in the Sun, supplemented by observations for special research. It is not too much to hope that the observations made during the last cycle, which gave the first evidence of the alternation of the magnetic polarities of sunspots, data for the measurement of the Sun's general magnetic field, and a fresh conception of the constitution of the Sun's outer layers, may be followed by others in which may lie the solution of the origin of the spots and the many allied problems of the solar atmosphere.

[1] *Astrophysical Journal*, **60**, 43, 1924.

THE X-RAY ANALYSIS OF ORGANIC COMPOUNDS

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The great change which has come over physics in the last twenty or thirty years is due to one fact in particular, to the fact that, instead of studying the behaviour of vast crowds of atoms and molecules and endeavouring, from that study, to deduce the properties of the individual, we concentrate more and more on the individual and try to deduce the probable behaviour of the crowd. The newer method is, of course, the more logical one, and has been made possible by two of the great discoveries of modern times—radio-activity and X-rays. Each of these has given us the power of probing into the innermost depths of matter, and, although we are still unskilled in the use of these new weapons, each has led to important progress. It is proposed here to give a brief survey of a few of the results which X-rays have given us. First let us see how it is that X-rays have enabled us to study the behaviour of small groups of atoms and molecules. Before we can see an object it is necessary that it should be at least comparable in size with the wave-length of the light by which we hope to see it. If it is small compared with the wave-length we are using, the waves will pass over it without being in any way affected by it. A simple calculation shows us that if we are to " see " atoms and molecules—and this must surely be the ultimate aim of physics and chemistry—we must use, not those waves to which the eye responds, but a variety of light whose wave-length is some ten thousand times shorter ; and this is exactly what Röntgen provided for us when he discovered X-rays. We have now at our disposal a light of such fine structure that the atoms and molecules, small as they are, are yet large enough to affect the waves. However, although the effect is there, our instruments are still too crude to detect the influence of a single atom or small group of atoms : we must in some way amplify the effect. Nature has provided us with a suitable amplifier in the crystal.

It has long been recognised that the only way in which a crystal could be formed was by the continued repetition of some small unit, a cell containing but a few atoms or molecules, which, repeated again and again in all directions, eventually grew to a size large enough for us to see. It resembles, in fact, a large number of boxes all arranged side by side, row after row, each box being exactly like its neighbours in size and shape, and each containing a small group of atoms packed in precisely similar fashion. Whatever effect one of these units has on the X-rays, an exactly similar effect will each of the others have, so that in this way we can, as it were, amplify the effect of the unit cell until it is large enough to be detected by our instruments. There is no need to enter into the technical details of the various methods of measurement ; suffice to say that in this way we can measure the length, breadth, and depth of the unit parallelopiped with an accuracy comparable with that which we attain in ordinary measurements of length, although the actual value of the length is some hundred million times smaller than those we ordinarily measure. Further, we can determine how many atoms or molecules of the substance the unit contains and a good deal as to the way in which these are packed into the cell. The full facts are there ready for us, but as yet we are far from skilful at interpreting our results.

In this way we can study the crystal, and we are in no way confined to large crystals. Any substance which is crystalline can be examined even if the small crystals of which it is composed are only of microscopic size. The crystals may even be so small that it is only by means of the X-rays themselves that we can realise their existence. In short, instead of speaking of crystals it would perhaps be better to speak of solids, since practically all solids are crystalline. We have in fact a method which tells us how the atoms and molecules pack together to form the solid. We can, in some cases at least, find out a good deal as to the structure of the molecule itself and the way in which it combines with its neighbours—the essence, indeed, of what is really a new science—the chemistry of the solid state.

The science of chemistry has, for the most part, concerned itself with the nature of molecules as they appear in the liquid state or in solution. When we study the solid state we have no reason to suppose that we shall find that the molecules with which we have to deal are exactly the same as those which have been the subject of the chemist's investigations. One of the principal problems which we have to discuss is the difference, if any, between the molecule in the solid and the molecule in solution. Many chemists have maintained that the two are quite distinct, and have described the molecules in the solid as dead compared with their more lively prototypes in solution. Whatever the difference between the two—a question on which more will be said later—there is one feature which definitely distinguishes the solid from the liquid, and which gives to the solid its characteristic features. In the solution, at any rate when we confine ourselves to molecules which are not dissociated, the unit of structure is the chemical molecule ; in the solid, on the other hand, the unit is a group of molecules definitely associated with each other and oriented relative to one another in a very characteristic way. Each of these solid molecules contains the same material as the chemical molecule, and the group is packed into the unit cell of the solid. All the properties of the solid as distinct from those of the liquid are to be traced to this fact, that in the solid the unit is not the single molecule, but this small group, each member of which has the same mass content as the chemical molecule. Thus, for example, the molecule of naphthalene in solution is $C_{10}H_8$, but in the solid the unit consists of two groups of $C_{10}H_8$ which are so related to each other that the one is the mirror image of the other in a plane. In the same way in tartaric acid we find in the small unit cell not a single molecule of the substance but two ; in this case the one molecule can be derived from the other not by reflection in a plane but by a rotation of 180° about an axis. It is in these characteristic groupings in the fundamental cells that we must search for an explanation of the properties of the solid substances.

It has been said that each of the cells contains an amount of matter equivalent to a small number of chemical molecules, and the question naturally arises—can we consider the cell as containing a group of molecules each of which is identical with the molecule as studied by the chemist in solution ? If we can answer this question in the affirmative, if we can even say, with reasonable certainty, that the crystal molecule closely resembles the chemical molecule, then the whole investigation of crystals by X-ray methods becomes one of great importance to the chemist and not merely to the crystallographer. In what follows it is hoped that evidence will be produced tending to show that there is, in the organic field at least, a very close similarity between the two types of molecule.

During the past ten years a very great deal of work has been carried out on the X-ray analysis of crystals, and the range of substances thus examined covers a very large field. Naturally, in the early days, attention was more or less confined to the elements themselves and to simple compounds, especially those which readily formed good crystals. A beginning has now been made on more complex substances both organic and inorganic. Although in some directions there are difficulties to be overcome in the study of organic substances which are less acute in the inorganic field, from other points of view the work is, perhaps, easier. In the first place organic chemistry is a much more highly developed science than inorganic. The extraordinary progress of structural chemistry has resulted in a very considerable knowledge of the actual arrangements of the atoms in the vast majority of organic compounds, while comparatively little is known as to the spatial arrangements of the atoms in inorganic substances. Again, in inorganic solutions, dissociation continually occurs, a complication which is generally absent from organic solutions. Further, there exist long series of organic compounds, each compound differing in only some small particular from its neighbours in the series, so that it is possible to watch, as it were, the gradual building up of a complicated molecule from a relatively simple beginning. Against these advantages must be placed the disadvantage that, in general, organic compounds are difficult to obtain in the form of good crystals, and very often the X-ray analysis has to be carried out, not with single crystals, but with crystalline powders.

Space forbids anything like a full description of the work which has been accomplished, but perhaps a few details as to some of the results in the organic field may be given. The first substances to be investigated were naphthalene and anthracene. These two form crystals which have many points of similarity, and it was shown by Sir W. H. Bragg[1] that this similarity extended to the unit cells from which these structures arose. His measurements gave the following data for the sides and angles of the cells :

Naphthalene $C_{10}H_8$ $a = 8{\cdot}34, b = 5{\cdot}98, c = 8{\cdot}68, \alpha = \gamma = 90°$, $\beta = 122° \, 44'$,
Anthracene $C_{14}H_{10}$ $a = 8{\cdot}58, b = 6{\cdot}02, c = 11{\cdot}18, \alpha = \gamma = 90°$, $\beta = 125° \, 0'$,
the unit of length being the Ångstrom unit, or 10^{-8} cm.

It will be seen that the a and b axes and the angles of the cells are very nearly the same, but the c axis of anthracene is considerably longer than that of naphthalene. This difference in the c axis immediately suggested the difference in the lengths of the two molecules, anthracene having three benzene rings end to end, while in naphthalene there are only two. From the X-ray measurements alone it was clearly impossible at this stage to place in position the ten carbons and eight hydrogens of each of the two molecules which were contained in the cell. However, in both crystalline forms of carbon, diamond and graphite, there occur series of closed rings of six carbon atoms, the rings being of approximately equal size in the two crystals, and Bragg made the assumption that these rings were similar to the benzene rings. He was thus able to calculate the dimensions of the naphthalene and anthracene molecules from the known dimensions of the rings in the diamond. When this was done, it was found that there was just room for the naphthalene molecule to arrange itself with its long direction along the *c* axis, and that the difference in the length between the *c* axes in naphthalene and anthracene was just what was required for the extra ring of the latter. Again, the constancy of the cross-section of the two cells was explained by the fact that it was determined not by the length of the molecule, but by the breadth and thickness of a single ring. The actual dimensions of the *a* and *b* axes were what was necessary for the side-by-side linking of the two molecules which the cell contained.

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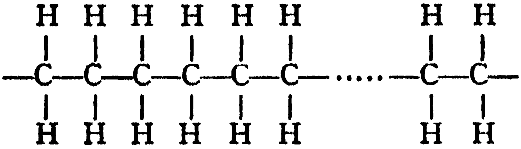
[1] W. H. Bragg, *Proc. Phys. Soc.*, **34**, 33, 1921 ; **35**, 167, 1923.

Another consideration which arose out of this investigation was concerned with the symmetry of these molecules. They form crystals of the monoclinic prismatic class possessing a plane of symmetry and a twofold axis perpendicular to this plane. These two elements of symmetry involve a centre of symmetry. If the molecules are asymmetric it is easy to show that there must be at least four molecules in the cell, the second being obtained from the first by a rotation of 180° about the axis, and the other two from the first pair by reflection in the plane of symmetry. In actual fact only two molecules were found in the cells, so that it followed that the molecules must themselves possess some of the symmetry of the crystal. Bragg was able to show that the molecules had a centre of symmetry.

Hence the results of this first venture into the organic field were most encouraging. They showed that if the benzene ring were given the dimensions of the closed ring of six carbons which is such a characteristic feature of the diamond structure, a very satisfactory packing of the molecules into the cells could be obtained, a packing which was in agreement with the X-ray data and which was also successful in explaining such properties as the extreme ease of cleavage in one direction of the naphthalene and anthracene crystals. Furthermore, the investigation threw light on the symmetry of the molecules in the solid state.

Since this early work many other aromatic compounds have been studied. The results all appear to be consistent with the assumption of a ring of this size as the basis of the benzene molecule. Much more work must be done before we can definitely say what is the exact configuration of the ring, whether it is precisely what we find in the diamond or the flatter ring of graphite, or whether it differs in detail from both of these. It will be surprising, however, if any very drastic alterations are found necessary.

The other great branch of organic chemistry, that which deals with the aliphatic series, has only very recently received attention. In many of the aliphatic series the lower members are liquids at ordinary temperatures so that the work has been more or less confined to the higher members of the series. Here the difficulties of obtaining good crystals are very great, and so far the major part of the work has been an attempt to interpret the X-ray spectra obtained from powders. In general the interpretation of a powder photograph is a very difficult task except in the simplest cases, but these aliphatic compounds, the basis of whose structure is a long chain of carbon atoms of the form



$$\begin{array}{ccccccccccccccccccc}
 & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & & & \mathrm{H} & & \mathrm{H} & \\
 & | & & | & & | & & | & & | & & | & & & & | & & | & \\
- & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \cdots\cdots & - & \mathrm{C} & - & \mathrm{C} & - \\
 & | & & | & & | & & | & & | & & | & & & & | & & | & \\
 & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & & & \mathrm{H} & & \mathrm{H} &
\end{array}$$

have one very characteristic property. The unit cells into which these long chain molecules are packed have one side which is very much greater than the others, and it is found that this side grows uniformly as the number of carbon atoms in the molecule is increased. In general it is not to be expected that there will be a simple relation between the linear dimensions of the cell and those of the molecules it contains, but in the case of these series the regular increase of one side of the cell with increase of the carbon content of the molecule shows that here there is such a relation. Further, the evidence strongly points to the fact that the other two dimensions of the cells remain very nearly constant throughout the series, and that the only change in the cell is in the direction of its length, a phenomenon similar to that found in the case of naphthalene and anthracene, but now extending over a much greater range, perhaps as many as twenty or thirty carbons. It must be remembered that what is measured by the X-rays is the perpendicular distance between successive identical planes in the crystal, and even when we find that this distance increases uniformly as the length of the molecules increases, we are not justified in deducing that the molecules are all arranged perpendicular to these planes. The direction of length of the molecules may, in fact, be inclined at any angle to the normal to the planes, but the tilt of the molecule must remain approximately the same throughout the series. Were it not so, there would be no simple law connecting the carbon content and the length of the cell.

In addition to the steady increase of the length of the cell as CH$_2$ groups are added, another feature of the spectra is of interest. In certain series it is found that the spacing apart of these planes as measured by X-rays is just about what would be expected if there were a single layer of molecules all parallel to one another and standing more or less upright between successive planes : in other series the spacing is twice as great for the same carbon content of the molecule and the increase per CH_2 group correspondingly large. This would mean that in the latter series the successive planes are separated, not by a single layer of molecules but by a double layer, the one set of molecules standing on top of the other set. There seems to be a very simple rule deciding which of these two formations will occur. If, at one end of the molecule, there is a group which is chemically active, like the COOH group in the acids, then the double layer will be found ; if both ends of the molecule are inactive chemically, as in the hydrocarbons where the end groups are CH_3, then only the single layer will appear. This rule, while purely empirical, appears to be satisfied by quite a large number of series, and it seems natural to conclude that when we find the double layer, the two sets of molecules are oppositely oriented, the active groups of the first set being directed towards the active groups of the second.

One series which has been investigated proved interesting in this connection—that of the normal saturated aliphatic ketones of general formula $CH_3{\cdot}(CH_2)_m{\cdot}CO{\cdot}(CH_2)_n{\cdot}CH_3$. The end groups are CH_3, and must be considered as inactive. It was therefore to be expected that the X-ray measurements would indicate the existence of only a single layer between successive planes ; and indeed this was found to be the case in the majority of the ketones. There were, however, a few exceptions which gave spacings twice as great as were expected, pointing to the existence of a double layer. These were not distributed at random, but were all methyl ketones of formula $CH_3{\cdot}(CH_2)_n{\cdot}CO{\cdot}CH_3$. In these cases the CO group was as near as possible to the end of the molecule, sufficiently near in fact to convert the end of the molecule into an active one consisting of the group $COCH_3$. If the oxygen was moved one place farther from the end, to give the ethyl ketones of formula $CH_3{\cdot}(CH_2)_n{\cdot}CO{\cdot}CH_2{\cdot}CH_3$, the effect vanished, the oxygen being now too far from the end to make its influence felt. A similar behaviour was observed in the ester series, $CH_3{\cdot}(CH_2)_m{\cdot}CO{\cdot}O{\cdot}(CH_2)_n{\cdot}CH_3$. The majority showed, like the ketones, a single layer, but the acetates, $CH_3{\cdot}(CH_2)_n{\cdot}O{\cdot}CO{\cdot}CH_3$, gave much greater spacings, again suggesting the double layer. The methyl esters $CH_3{\cdot}(CH_2)_n{\cdot}CO{\cdot}O{\cdot}CH_3$, which gave only the single layer, suggested that it was the double-bonded oxygen and not the oxygen in the chain which was responsible for the activity.

These measurements bring home to us very clearly that the basis of the molecules in these aliphatic series is a long open chain of carbon atoms ; that the molecule increases uniformly in length with the addition of CH_2 groups. The actual measurements of the lengths of the molecules is complicated by the fact that we do not know the angle which the molecules make with the planes whose distance apart we measure, but perhaps a little speculation as to the nature and dimensions of the chains is justifiable. Once more we turn to the diamond structure for a suggestion. Throughout the diamond there run in all directions zig-zag chains of carbon atoms, all the carbons being in the same plane and the angle of the zig-zag being the tetrahedral angle of 109° 28′. In the diamond we know the dimensions of these chains, and we find that the addition of a carbon to the chain results in an increase of its length of 1·26 Å.U. (1 Å.U. = 10^{-8} cm.) In the aliphatic series so far examined, it has been found that the rate of increase per CH_2 group of the distance between successive planes, after allowance for the double layer where it exists, has a strong tendency to approximate to one or other of two values, one about 1·05, the other about 1·27 Å.U. The latter value is very nearly the same as that found in the diamond, so that, if we assume the chains to be identical, molecules in the series which show this rate of change must be arranged very nearly normal to the planes. If the chain structure remains unaltered, the value 1·05 must result from a decided tilt of the molecules away from the normal. The tilt would have to be about 30°, and it is interesting to find that in the only single crystal measurements which have so far been made, those of stearic acid, the angle between the *a* and *c* axes of the monoclinic crystals is 59·7°, so that the angle between the *c* axis and the normal to the *c* plane is 30·3°. Further, stearic acid belongs to one of the series which show the smaller rate of increase. Until many more single crystals of typical members of the various series have been examined, it is impossible to arrive at definite conclusions, but, on the whole, the balance of evidence at present suggests that the chain of carbons which forms the basis of these molecules resembles closely the zig-zag chain of the diamond. It is interesting in this connection to notice that there is a very decided tendency in monoclinic crystals for the angle β to approximate to one or other of the two values 90° or 60°, and the two rates of increase observed in the aliphatic series suggest that what really occurs is not two different types of chain but one type only, and that the observed difference is due to a variation in the angle which the direction of length of the molecule makes with the normal to the cleavage plane.

While the length of the molecule appears to be determined by the number of carbons it contains, it is possible to observe the effect of an irregularity in the chain such as the CO group in the ketone series. The length of the ketone molecule does not depend on the position of this group, but only on the total number of carbons. On the other hand the carbonyl group has a very noticeable effect on the distribution of intensity among the various orders of reflection from the large spacing planes. A very large number of these orders can be observed, and it is possible, on simple assumptions which need not be detailed here, to calculate the variation in the distribution of intensity according to the position of the oxygen atom in the chain. Thus, for example, if the oxygen is half-way along the length of the molecule, the even orders will be very weak relative to the odd orders; if it is one-third of the way along, the third, sixth, ninth, etc., orders will tend to disappear, and so on. Comparison with experiment shows a good agreement with the theory, good enough, indeed, to enable us to fix with reasonable accuracy the position of the carbonyl group by a qualitative examination of the intensity distribution. In this way, too, we find a confirmation of the assumption that in the structures of chain compounds which show a double layer, these layers are oppositely oriented. The observed intensities are in agreement with calculations based on this assumption, and would be in entire disagreement with the hypothesis that the two molecules were placed end to end in the same direction. Also the di-n-ketones of formula $CH_3 \cdot (CH_2)_n \cdot CO \cdot (CH_2)_n \cdot CH_3$ show intensities very similar to those of many of the double spacing series. Although in these there is only a single layer of molecules, it is clear that they might be considered as a double layer of half molecules $CH_3 \cdot (CH_2)_n \cdot \frac{1}{2}(CO)$, placed end to end in opposite directions.

The results of the X-ray measurements of these compounds have been dealt with at perhaps undue length, because it appears that even the preliminary results of their investigation suggest strongly the similarity of the molecule as described by the chemist to that found in the solid state. Even if all that had been known as to the structure of these molecules had been their carbon content, the X-ray spectra would immediately have suggested that the key to their structural formula was a long chain of carbon atoms. The X-ray data would have been impossible to reconcile in any simple way with a ring formation or with a ring formation combined with a chain. The X-ray work confirms in a striking way all the conclusions reached by the chemist, so that it would appear that the molecule in the crystal is, in these cases at any rate, extremely like the molecule in solution.

The characteristic grouping of the molecules which form the contents of the unit cell must in the end serve to explain all the physical properties of the solid. At the present stage of development we are far from being able to offer anything like a complete explanation, but already some interesting attempts have been made in this direction. Tartaric acid offers an example. One of its most notable properties is its power of rotating the plane of polarisation of light. In both the solid state and in solution tartaric acid has this property, but the rotation in solution differs in magnitude and direction from the rotation in the solid. Astbury,[1] who worked out its structure by X-ray examination, has made an interesting suggestion to explain this. Following Bragg's idea that the rotatory power was the result of some spiral arrangement of the atoms, Astbury found that two such spirals could be identified in the structure. One was connected with the four central carbon atoms of the molecule, while the second resulted from the way in which the molecules combined to form the crystal unit. These two spirals were in opposite directions, so that in the solid the resultant rotation would be the difference of the two. In the liquid, on the other hand, only one spiral existed, that connected with the central carbons. Thus, at least, a qualitative explanation of the rotatory dispersion of tartaric acid appeared to follow from the structure suggested by the X-ray examination. The subject is still too undeveloped for us to expect to be able to explain all the properties of the solid, and it will only be after a prolonged investigation of a series of compounds which show some characteristic property that we can hope to find what special configuration gives rise to the property in question.

Besides throwing light on the spatial arrangements of the atoms in the molecule, and demonstrating how it is that the molecules are packed together in the solid, it is possible that X-ray analysis may be of service in the determination of molecular weights in cases where the ordinary methods fail or are difficult to apply. We can measure the dimensions of the cell, and therefore, if we know the density, the mass. We also know how many molecules are necessarily present in the cell in order that it may show the symmetry peculiar to its crystal class. If the molecule itself possesses no symmetry, and the great majority of complicated organic molecules must be asymmetric, then, by dividing the mass of the cell by the necessary number of molecules, we determine the mass of the single molecule. This assumes that the minimum number of molecules necessary for the symmetry is present in the cell. Thus, if the crystal possesses only a twofold axis of symmetry, two molecules are necessary, the second derived from the first by a rotation of 180° about the axis. There is no mathematical reason why there should not be present in the cell any multiple of this number, but it would appear to be a fairly general rule that nature uses only the minimum amount of material to attain its ends. When, as occasionally happens, we find more molecules than are necessary, it is probable that some form of chemical polymerisation is taking place. This is essentially different from the grouping together of a number of molecules to form the crystal unit. That combination results in the group having the symmetry which the crystal shows, whereas the other type merely results in a combination of molecules without the introduction of symmetry, and it seems probable that it is very similar to ordinary chemical polymerisation. We should expect to find that when the solid shows this polymerisation, it will also be present in solution, and in most cases we do find evidence of its existence. There are some exceptions, notably fumaric acid. Miss Yardley[1] has shown that there are six molecules in the unit triclinic cell whereas we should not expect more than two. In the solid it would appear that the molecular formula is $(C_2H_2(CO_2H)_2)_3$, and not $(C_2H_2(CO_2H)_2)$. It is to be expected that when polymerisation occurs in solution it will also be present in the solid, but it is interesting to find evidence of it in the solid where none was suspected in the solution. In the case of very complicated molecules whose molecular weight determinations are difficult or in cases where polymerisation may occur, it may perhaps be helpful to combine the chemical methods with an X-ray analysis of the solid substance.

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[1] W. T. Astbury, *Proc. Roy. Soc. A.*, **102**, 506, 1923.

In this account it has only been possible to describe a few of the results obtained in the organic field, and no mention has been made of the interesting work which has been done along other lines. A great many inorganic substances have now been examined, and it is perhaps in this direction that the chemist will find X-rays most helpful. In fact, at present it would seem that only by X-ray analysis can inorganic chemistry be placed on as sound a structural basis as organic. In that field also, much valuable work has been done in attempts to explain the properties of the various substances in terms of the relative positions of the various atoms in the fundamental unit; one of the most notable recent achievements being W. L. Bragg's evaluation of the two refractive indices of calcite from calculations based on the structure of the unit cell.

In the twelve years which have passed since the earliest experiments, the progress has been rapid, and although it may be admitted that up to the present X-rays have told the chemist little that he did not know without their aid, it seems more than likely that in the future no research chemical laboratory will be complete without an X-ray spectrometer, whether the aims of the laboratory are to extend pure chemistry or to further its applications to industry.

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[1] K. Yardley, *J.C.S.*, 127, 2207, 1925.

THE RECAPITULATION THEORY

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THE so-called biogenetic law of Haeckel, that the developing organism, in its growth from the egg to the adult stage, "recapitulates" the past history of the race, was one of the most fascinating additions to the theory of evolution which was made during the nineteenth century. The publication of the first edition of the *Origin of Species* took place in 1859, and Haeckel's *General Morphology*, in which this law was enunciated, appeared in 1866. The belief in the validity of this law was the stimulating impulse to zoological research for over forty years. The enthusiasm evoked by it, particularly in the younger men of the time, can be understood when we reflect upon the clues actually available for following up the course of evolution.

There are, in fact, three sources of evidence for the ancestry of existing forms, viz. (1) the comparative study of allied species, (2) the study of fossils, and (3) the study of development. The comparison with one another of allied species yields valuable information as to the most recent steps in evolution. When we find a uniform type of structure prevailing throughout almost all the members of a group of animals, and one or two exhibit divergences from this type, then we feel convinced that the type is older and that the divergences are recent developments of it. There is of course, and can be, no absolute proof that this is so; but the fact that all serious students of the animals in question feel unable to come to any other conclusion is presumptive proof enough for all reasonable men. Thus we feel sure that the air-breathing catfish of India (Clarias) with its curious pulmonary trees has been recently evolved from an ordinary type of cat-fish, that the flying-squirrel (Sciuropterus), with its parachute-like fold of skin extending between knee and elbow, is a development from the ordinary kind of squirrel. When, however, we attempt to follow the evolutionary process farther back, and connect together different orders or classes, our conclusions grow more and more uncertain. All such attempts implicitly assume that some group of animals has stood still, whilst an allied group has progressed in evolution.

This may have happened, but it is utterly impossible to be sure that it has actually occurred. Attempts have been made to show that Mollusca, for instance, are descended from Platyhelminthes or from Sagitta. We can in imagination construct an intermediate series of types; but did such types actually exist? One zoologist thinks they may have existed, another that they did not, and the general feeling of those taking no part in the controversy is that no certainty at all can be attained on the subject, and that the further inquiry into such questions is waste of time.

The study of fossils offers a much better promise of throwing light on the progress of evolution than the study of living forms. In certain favourable localities, especially in America, there are continuous series of beds thousands of feet thick and richly fossiliferous. We find the remains of a certain kind of animal in the lowest beds, and as we ascend in the series we find the remains of other animals closely allied to those in the basal beds, but diverging more and more as we approach the top of the series; and the conclusion is irresistibly forced on us that we are dealing with an evolutionary history. If, to take an instance, we examine the series of primitive horses of Oligocene date, we find that they all had three well-developed toes on both fore- and hind-feet. As we pass upwards in the series toward Miocene and Pliocene beds, the outer toes slowly diminish in size, until in modern horses they are represented by the vestigial splint bones hidden under the skin. Yet the process is so gradual, and immediately succeeding types resemble one another so closely, that as one eminent palæontologist expressed it to me: "I assure you that these lateral toes diminish in size only by millimeters at a time." We may cordially agree with Huxley in stating that in such successions we get at once the final proof of the evolution theory, and the best light on its actual course. Nevertheless, this light illuminates at best a very limited field. It is a truism to say that only the hard parts of extinct animals are preserved, and these hard parts are only of value when they stand in close relation to the general morphology of the soft parts. Thus in the phyla Vertebrata and in Arthropoda we get a very fair idea of what extinct forms were like from the study of their skeletons, but although we have abundant remains of Mollusca, who would venture to deduce anything as to the condition of the internal structure of the animals from their shells? We can trace beautiful evolutionary series in the development of the folding of the edges of the septa and of the external sculpturing of the shells of Ammonites, but what were the animals like which inhabited them? Had they the primitive structure of the living Nautilus, or were they like Spirula which still retains a coiled, chambered shell, but is in other respects a very ordinary cuttle-fish? Who can tell?

If, however, embryology really is a recapitulation of past history, thence, since all the higher animals begin their life-histories as eggs, which in general structure are fundamentally similar to the lowest protozoa, we have the prospect opened to us of tracing the history of life from the very beginning; and it was the insight into the vast possibilities enshrined in the study of embryology that led Haeckel to pen his *Schöpfungsgeschichte*.

When, however, we look into the reasons for this belief we find that they are all deductions from the other two classes of evidence. We select cases where a portion of the evolutionary history is made plain, either by the study of allied forms or of fossils, and then we compare this record with the information derived from the life-history of a living form, and it is the startling agreement between the two classes of evidence, which in many cases we obtain, which drives home the conviction that in the embryological record we are really dealing with racial history. One or two striking instances of this agreement may be given. We have already mentioned the Indian cat-fish Clarias, which differs from other cat-fish in breathing air and in having two tree-like organs for absorbing air growing out above its gills. From comparative anatomy we deduce that Clarias is derived from ordinary cat-fish, and that these modifications of its structure are recent innovations. Now when young post-larval Clarias are examined they are found to be in all respects similar to ordinary cat-fish and they live exclusively in the water. Only as they grow older do they begin to emerge into the air, and to acquire their pulmonary trees.

Again, it is a familiar fact to comparative anatomists that the hinge of the lower jaw and skull is differently constructed in Mammals from what it is in Reptiles and Birds. In the two latter classes the lower jaw is a composite structure consisting of at least five bones, and one of these (the articular) hinges with a squarish bone called the quadrate, which is either loosely or immovably joined to the bones of the skull. The bony style, which connects the inner and outer drums of the ear (the fenestra ovalis and the tympanic membrane) is a single slender bone. In Mammals, on the other hand, the lower jaw is a single bone, termed the dentary, corresponding to one of the five bones of the lower jaw of the Reptile, which is *not* involved in the articulation. But in Mammals the dentary articulates directly with one of the covering bones of the skull (the squamosal), and the inner and outer drums of the ear are connected by a chain of small bones, viz. the stapes, the incus, and the malleus, of which the first is pressed against the inner drum.

Now the study of the skulls of adult living forms led to the conclusion, that in developing out of Reptiles, Mammals had transformed the ancestral quadrate into the tympanic, a bone which encircles the base of the outer ear. The study of mammalian embryos, on the other hand, led to the paradoxical result that the reptilian articular bone had become the mammalian malleus, and that the quadrate had been transformed into the incus. If this was really a record of racial history it was very difficult to see how the various steps of it could have been realised in actual living functioning ancestors. So at the time of my own student-life it was customary to regard this development as a secondary modification and not as a record of history, and to give preference to the view of evolution suggested by the comparison of adult skulls. Since that time the fossil record recovered from skulls preserved in the Permian and Triassic deposits of Africa has shown that the embryological story of racial history is correct, and we have demonstrated before our eyes how the intermediate stages actually worked.

Again, all students of zoology are agreed that somehow the five-fingered hand of land vertebrates has been developed out of a fish's fin, and most would admit that it must have come from the peculiar feather-shaped fin of the Devonian fish, which immediately preceded the first newt-like Amphibians. Now Steiner, from a study of the embryonic development of the bird's wing, has arrived at the conclusion that the fourth finger represents the original axis of the feather-like fin, the fifth finger being the only remnant of the post-axial rays remaining, whilst the first, second, and third fingers represent the pre-axial rays. Prof. D. M. Watson from the study of the fossil Crossopterygian fish of the Devonian has independently arrived at exactly the same conclusion !

But every embryologist, from Haeckel onwards, is ready to admit that there are other factors beside racial history involved in fashioning the embryological record. These secondary factors, which Balfour called " falsifications of the record," are of many kinds, and it was the neglect of the duty of trying to define and eliminate these which, during the later years of the nineteenth century and the opening part of twentieth century, brought the recapitulatory interpretation of embryology into disrepute. Enthusiastic workers championed different views of the ancestry of the same class ; any awkward features of the life-history difficult to reconcile with their particular views were instantly dismissed as secondary ; and animals were regarded as capable of the most extraordinary feats, such as forming a new mouth or a new anus, or even an entirely new alimentary canal, leaving the old one to serve as the central canal of the nervous system!

It would occupy far too much space were we to deal with all these secondary features in detail; we propose to consider carefully only one of them, namely the mutual relationship of the embryonic and larval phases of development, and to bestow a passing glance on one or two others. We call a developmental stage an embryo when it is sheltered within an egg or within the maternal womb, being fed in the first case by yolk stored in its protoplasm, and in the second case by the secretions of the mother. We call a development stage a larva when it moves freely about and seeks its own food. In every life-history there is both an embryonic and a larval phase, for no animal lays naked eggs; and so the earliest stages of development are always passed within the shelter of an egg-shell or a womb, and no animal, when it finally emerges from the egg-shell or from the womb of the mother, is exactly like the parent, and so the concluding stages of development are always larval.

Now the question at once arises, Is the embryo a secondary, modified larva, or the larval stage a secondary falsification of the story of development? From the fact that the latest phase of development, which is the most recent chapter added to the life-history, is always larval we should be forced to draw the conclusion that the larval phase is the primary one. But the opposite opinion has been stated by high authorities. The most familiar larva to us all is the tadpole of the frog, and we note that Boulenger in his account of the Anura of Europe declares his belief that the tadpole stage is a secondarily intercalated phase in the ontogeny. We shall now adduce some evidence to show that the larval phase is really primary.

There are two Salamanders in Europe, viz. the Fire Salamander (*S. maculosa*), which has a black skin diversified by yellow spots, and the Black Salamander (*S. atra*), with a purely black skin. Both species are viviparous, but the young of *S. maculosa* are provided with long, feathery external gills, and when born take to the water and live in it for six months before emerging to take up land life. The young of *S. atra* on the contrary are devoid of gills, and at once take to land life. Yet if the womb of a pregnant *S. atra* be opened embryos with long, feathery gills are seen therein, and if these embryos are thrown into water some will survive and live in it and eventually metamorphose and come on land just like the young of *S. maculosa*. Again, if we examine the Anura (frogs and toads) in which a typical tadpole phase occurs in the life-history, we do find some species with what is called "direct development", in which no tadpole stage is found. Such a form, for instance, is Hylodes, the tree-toad of the West Indies represented by various species in the different islands. From the somewhat large eggs of this form there emerge little froglings, ready to live on land. But if the developing egg be opened, there is found within it a perfectly formed tadpole with gills and tail.

Such instances could be multiplied, and they make it perfectly clear that the embryo is a modified larva. The credit for this far-reaching conclusion belongs to the late Prof. Sedgwick, who enunciated it in 1894, and we may now briefly study the modifications which the embryonic mode of life entails.

The larva has to make use of its organs of sensation, movement, and nutrition ; it must discover its food, chase and seize it, and digest it ; it must also evade its enemies. Therefore its organs must be functional ; but the embryo has to make no exertions to get its food, and its organs during embryonic life have no function ; and so they become simplified till they may be reduced to mere sketches of the ancestral organs. The alimentary canal may be solid in whole or in part ; the mouth may be temporarily occluded, for no nourishment is taken by the mouth, and it is the uncritical interpretation of facts like these which has led to the wild theories to which we have alluded above.

We may illustrate these secondary modifications by considering the case of the Nauplius larva of the Crustacea. This larva has led to a famous controversy, and it shows in the clearest way what is the real nature of the recapitulatory element. It is typically a little oval, unsegmented creature, with a ventral mouth covered by a very large upper lip and a terminal anus. There are three pairs of legs, one pair consisting of a very few joints and unbranched, being situated in front of the mouth and acting as feelers, and two pairs behind the mouth both forked, and in each case carrying a so-called masticatory hook on the inner branch. Fritz Müller, who first described the larva, regarded it as representing the veritable ancestor of all the Crustacea, for it occurs in typical form in the great groups of the Phyllopoda, Copepoda, Cirripedia, and the Malacostraca. Amongst the Ostracoda it is also present, but in a secondarily modified form. He concluded, therefore, that the Crustacea were sprung from a stock of small, unsegmented creatures, and that segmentation had been secondarily developed amongst them. Hathchek pointed out that such a view would cut the Crustacea off from all relationship with the Insecta and Arachnida, the youngest stages of which exhibit well-marked segmentation. We shall discuss the merits of this dispute later. We may now examine what happens in the development of the higher Malacostraca (crabs, lobsters, shrimps), in which the embryo emerges from the shell as a segmented animal with numerous appendages. If we open the eggs of these creatures at earlier stages of development, we find a well-marked stage with only three pairs of appendages altogether, and only one pair in front of the mouth. At this stage there is a distinct pause in development, and a cuticle is thrown off, in fact an ecdysis or moult occurs within the egg-shell. This stage evidently corresponds to the Nauplius larva. But the Nauplius embryo, as we may call it, differs from the Nauplius larva in that the appendages are unjointed stumps; the alimentary canal is a swollen, rounded mass of yolk imperfectly covered with cells, and contained within the hump-like back; and the stomodæum, or ectodermal hall-way of the gut, which in the larva is in open free communication with the intestine, is in the embryo a blind pit. Yolk, indeed, is one of the principal offenders in the distortion of the embryological record. When it is present in quantity it swells up the part of the embryo in which it is lodged, and inhibits cell formation and development, so that whilst the rest of the embryo advances towards the adult condition, the part containing yolk remains relatively undeveloped, and forms an appendage, the well-known yolk-sac so familiar to students of the life-history of fish. But the other type of embryo, viz. that which absorbs secretions from the mother, is also liable to great distortion. This type, familiar to us all in the class Mammalia to which we ourselves belong, often converts a large portion of the embryonic surface into an organ (the placenta) for absorbing nutrition from the wall of the womb. This portion of the embryonic surface undergoes a transformation which renders its original condition quite unrecognisable, and so it comes about that the human embryo, which develops the most specialised placenta, is in its ventral portion represented by a stalk amd a flattened sac, whilst in its dorsal portion it exhibits the most ludicrous resemblance to the tadpole of a frog. The neck which in the tadpole separates the region of the gills from that of the trunk is clearly seen in the human embryo; it has nothing to do with the adult neck. The vessels supplying the gills in the tadpole are reduced in number and modified with the taking up of aerial life; those of the human embryo resemble those of the tadpoles and are reduced in the same order.

We may now return to the question of the ancestral significance of the Nauplius larva. The phylum Arthropoda, which includes as its main branches the Insecta, the Arachnida, and the Crustacea, is clearly related to the segmented worms. The embryos of Insecta and Arachnida in their segmentation and in their body-cavities show this unequivocally, and unless we accept the idea that the Arthropoda are not a natural group, but really include two fundamentally distinct strains which have acquired a superficial resemblance to one another, the view that Crustacea are derived from an unsegmented ancestor becomes untenable.

Now, although the various types of Nauplius larvæ agree in their broad, general features, they are by no means exactly alike. If, for instance, we examine the Nauplius larva of the Phyllopoda, we can find in it some most interesting features, not developed in other types of Nauplii. The Phyllopoda, on account of their flexible cuticle and the delicate leaf-like character of most of their appendages, are that group of Crustacea which most closely resemble worms, and are on that account regarded as the most primitive. The larvæ of the Phyllopod genus Chirocephalus, which I had the opportunity of seeing alive the other day, show, even before they leave the egg, a most distinct segmentation of the region behind the mouth, and in the Chirocephalus Nauplius, as in all other Phyllopod Nauplii, this region is unusually elongated. Dr. Cannon has shown that other Phyllopod Nauplii, even although they may hatch with this region unsegmented, acquire segmentation in it almost immediately afterwards, before any but the Naupliar appendages are developed. This larva, therefore, would indicate a segmental ancestor in which the first three pairs of appendages were greatly enlarged and modified, and played a dominating part in the life of the animal. The other segments may have had leaf-like appendages of little physiological importance ; if so, these have been suppressed, and are not represented in the larva. Now this conclusion fits in admirably with the known facts. The earliest Arthropoda known to us, and in many ways the most primitive, were the Trilobita. There was in the oldest of these a partial " cephalisation," that is a fusion of the first few segments to form a head. A similar cephalisation appears in an incipient form in some Annelidan worms. But with the exception of the unbranched jointed antenna, which is situated in front of the mouth, all the other appendages of the body, including those of the head, are similar to one another ; they are flattened leaf-like limbs, each divided into two branches, and each bearing on the inner branch a masticatory hook. Since, in the Nauplius, there is also only one appendage in front of the mouth, this larva might be almost described as a microscopic Trilobite, in which the first two post-oral pairs of limbs are enlarged and developed into powerful swimming organs. In the wonderful Mid-Cambrian fauna from British Columbia, described by Walcott, there occurs a peculiar Trilobite, which he has named *Marrella*, in which the second and third pairs of appendages are greatly enlarged, so as to form long, forked limbs, whilst the remaining limbs remain thin and foliaceous, and obviously physiologically unimportant. *Marrella* may, therefore, be the actual ancestor of Crustacea, which is represented by the Chirocephalus Nauplius.

To convert *Marella* into a primitive Crustacean it is necessary that the second appendage should migrate in front of the mouth and lose its masticatory process, and that the masticatory process of the third appendage should be enlarged, and the distal joint of this limb much reduced. These changes actually occur during the further growth of the Nauplius. *We see now that the recapitulation embodied in a larva consists essentially in the reproduction of a former physiological condition of the race.*

The functionally important organs of that state are developed and emphasised, whilst the relatively unimportant organs are suppressed. In a word, recapitulation may be compared to *memory* ; it really is the repetition of former habits. Nor is this comparison fanciful. The word " memory " is applied to denote two different things which, according to Bergson and McDougall, are of radically different nature. There is sensorial memory, by which is meant the return to consciousness of past scenes and events, and there is what we may call habitudinal memory, that is the revival of lost habits and lost skill. If, when young, we have learnt to play a game like golf or tennis, and then in the early years of manhood have had no time to practise it, and we take it up again in middle age, we shall find that a part, but not all, of our skill is revived. On the other hand, Bergson holds that as regards sensorial memory, nothing ever perceived and attended to is ever forgotten ; though it may be submerged in the sub-conscious stratum of our psychic life, it can be recalled if the appropriate stimulus is produced.

Now it has been recently proved that habitudinal memory is hereditary, and that, therefore, the phrase " racial memory " is justified, Kammerer enclosed specimens of *Salamandra maculosa* immediately after they had metamorphosed and taken up land-life in yellow boxes, and showed that as they grew to maturity the yellow patches on the integument grew in size. This experiment, though not accepted by Herbst, who tried to repeat it and failed, we ourselves have recently succeeded in confirming. When two " yellowed " specimens were mated together, they produced young which at metamorphosis were considerably yellower than their parents had been at the corresponding stage of development, and when these young were placed in black boxes *they steadily turned yellower for the first year of their lives*, and then, and then only, did the influence of the black environment begin to tell and the yellow spots diminished in size. *In a word, these young recapitulated the parental habits.* Similarly Durkhen, by enclosing the caterpillars of the ordinary white butterfly, *Pieris brassicæ*, in boxes with lids of orange-tinted glass, succeeded in getting pupæ of a bright-green colour. In these pupæ the chalky-white colour of the cuticle of the normal pupa was suppressed, and the green blood shone through. When these pupæ became imagines and were allowed to lay eggs and caterpillars were reared from these eggs, no less than 34 per cent. of the resulting pupæ were green, in spite of the fact that all the caterpillars had been exposed to bright, ordinary daylight. The results of these experiments, which are either not known to most zoologists or deliberately ignored by them, constitute the strongest argument in favour of the recapitulatory hypothesis that has been put forward.

Prof. W. Garstang[1] has recently made an attack on the doctrine of recapitulation in the *Journal of the Linnean Society*, and it would therefore seem appropriate to consider the arguments which he brings forward. It is a little difficult to be quite clear about his position, for it is really impossible for a competent marine biologist, and especially for a specialist in Tunicata, like Prof. Garstang, to deny the fact that the Tunicate tadpole indicates a former free-swimming ancestor of the Tunicata, which was provided with a notochord. But his arguments appear to be as follows: the Haeckelian presentation of the recapitulation theory implied that as an animal progressed in evolution, it added to the length of its life, and that it first traversed the period of life which its ancestors had enjoyed, and when it had reached what was formerly the adult condition, it then continued to live, and passed into a new adult form. This he asserts is absurd; evolution did not take place by the influence of the environment on the adult, but by inexplicable chance mutations in the eggs, which conferred on them new powers of development (the opening of a Pandora box of tricks as he fancifully calls it). As a result of these mutations, the former adult stage was replaced by a different one, and the larva represents, not an ancestral adult stage, but an old larval stage modified.

These theses Prof. Garstang endeavours to support by showing that the alleged ancestral stages in various life-histories do not correspond to any real ancestor of the race. In order to do this, he is forced to construct imaginary phylogenies of various groups of animals by the most dangerous of all methods, viz. the comparison with one another of living adult forms. It would require too detailed a discussion of the special anatomy of each separate group to show the radical unsoundness of Prof. Garstang's conclusions, but one delicious piece of bluff must not pass unnoticed. Prof. Garstang in referring to the alleged ancestral significance of the pro-legs on the abdomen of a caterpillar says : " The time has long passed when it was possible to regard these pro-legs as homologues and derivatives of the true legs of some Scolopendroid ancestor." In reply to this we may note that one of our foremost living entomologists, Dr. Tillyard, F.R.S., of the Cawthron Institute, New Zealand, holds this very view, and Prof. Garstang would have been well advised to have consulted more of the leading authorities in each group before he committed himself to such rash and dogmatic statements.

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[1] "The Theory of Recapitulation: a Critical Restatement of the Biogenetic Law," by Walter Garstang, M.A., D.Sc., Prof. of Zoology in the University of Leeds. *Linnean Society's Journal*, vol. xxxv, September 1922.

In answering an opponent, it is wise to examine and freely admit the element of truth contained in his arguments. We may agree with Prof. Garstang that it is unlikely that an animal in passing from stage to stage of evolution added new periods to the duration of its life, although even this contingency must be admitted in some cases. If we examine the group of the Nematoda, we find that the free-living forms, which are universally regarded as the most primitive members of the group, are minute worms, closely resembling the free-living larvæ (Rhabdites) of the parasitic forms. These little free-living forms produce only small ovaries containing few eggs ; and it is clear that if and when such forms in their search for food succeeded in penetrating the bodies of other animals and maintaining themselves there, their lives and their powers of growth, in the presence of abundant supplies of stimulating food would both undergo an indefinite amount of extension.

We hold no brief for Haeckel, and by no means subscribe to all his views, but does Prof. Garstang seriously suppose that such a vigorous and far-sighted biologist as Haeckel would overlook the obvious fact, that if the life-history of an animal became changed, the hereditary potentialities of the zygote must also have been changed ?

The question which arises is how the hereditary potentialities of the zygote have been altered, and on this subject we shall have a few words to say before closing this article.

But the answer to Prof. Garstang's supposed necessity of a continually lengthened duration of life is so clear and obvious that it is quite evident that he is not an embryologist, or he never would have posed this objection. The phrase " adult stage " is hopelessly ambiguous.

In life-histories, where there is a larval stage differing markedly from the adult stage, the metamorphosis is the record or "memory" of a change of habits which was made by the race at one period of its history, but when the "adult condition" is attained, growth does not cease. Herrick, in his monograph of the American lobster, figures what he calls the "adult stage" in a specimen 1½ inches long. The shore sea-urchin *Echinus miliaris* may attain a diameter of 2 inches; the development of the test of this species has recently been worked out in the laboratory of the Imperial College of Science, and all the adult features are present in a specimen ⅛ of an inch in diameter. It is obvious that if any species of animals is to undergo evolution, which means adopting new habits, especially in the matter of finding food, its organisation must be to some extent plastic, for as the proverb wisely says, "you cannot teach an old dog tricks"; but there is such a long period of growth *after the adult condition has been attained* that there is abundant scope for such a change. If we then say that the life-history records the changes which the "young adults" of other generations have undergone, we shall be justified by what we know of embryology, and we shall have removed Prof. Garstang's difficulty.

Prof. Garstang's other objections may be briefly dealt with. They resolve themselves into the argument that in most cases the larval stage cannot exactly resemble an ancestor. Neither Haeckel nor any other embryologist ever contended for such an absurd proposition as Prof. Garstang attributes to them. Haeckel says that ontogeny is a "shortened recapitulation" of phylogeny, and as we have already stated all students of embryology have admitted the existence of secondary modifying factors. We have tried to show that what is recapitulated is not ancestral structure as such, but ancestral habits or, perhaps we may more wisely say, an ancestral physiological condition—and this recapitulation or recall we have compared to ancestral memory. Just as no memory image, however vivid, retains all the details of the original sensorial presentation, so the structure of no ancestral stage is recorded in all its details, and steps in the process of blurring may be traced by comparing the larvæ of the same group of animals. We have shown the light which the Nauplius of the Phyllopod Chirocephalus throws on the ancestry of Crustacea. Other Nauplii, however, such as those of Copepoda and Malacostraca, have lost the long segmented abdomen which this Nauplius exhibits. Then again, just as a habit by constant repetition becomes more deeply engrained in the constitution and comes to be more quickly learned, so larval stages tend as time goes on to be passed through at an earlier period of growth, and the adult stage to be more quickly attained. The complete development of that primitive Mollusc Chiton has recently been worked out, and it is full of the most interesting ancestral reminiscences, but the "adult form" is attained when the beast is about half a millimetre long. This reduction in size of the larva as compared with the corresponding stage of the ancestor has entailed structural simplifications, which are fully discussed in our *Invertebrate Embryology*, to which the reader is referred.

In certain cases, however, as in the higher insects, the adult stage of life has become an extremely dangerous one, and is retained merely for the sake of a brief period of propagation. This condition of affairs is probably due to the enormous development of birds. Under these circumstances the larval life has been prolonged, and as all the nutrition has to be accomplished in this condition, secondary larval adaptations are numerous. We may sum up this discussion by saying that every life-history represents a blurred and partly falsified ancestral record ; and just as the historian extracts the truth from ancient, mutilated records disfigured by later interpolations, by stressing the points in which they agree and discounting those in which they differ, so must the comparative embryologist proceed, and only on the basis of a *comparative embryology* can any reliable record of ancestral history be founded.

Nothing surprises one more than the tone of dogmatic certainty about the actual course of phylogeny which Prof. Garstang thinks fit to adopt when endeavouring to discredit the embryological record. Thus, he says that there is no scrap of evidence that a stage like the filo-plumes of the nestling bird ever intervened between the condition of a reptilian scale and that of contour feather. The fact is that unless the structure and development of the filo-plume throws light on it, we have not a scrap of evidence that anything at all intervened between the scale and the feather !

So, too, he talks loftily of what happened when the ancestral Protozoon became the first Metazoon. All speculation on this subject is pure imagination unless we regard the egg as representing a Protozoon ancestor, and its segmentation as the record of the transformation of this ancestor into a Metazoon.

We come now to Prof. Garstang's final argument that evolution is due to "zygotic mutations," such as Morgan encountered in his cultures of Drosophila. "Who with Morgan's results on Drosophila before him would doubt that one adult stage may replace another ? "

To this argument we can only oppose the strongest denial that the English language is capable of conveying. We have alluded at the beginning of this article to the sources of our evidence for the course of evolution. Where this evidence is clearest, there is the most unequivocal testimony to the fact that evolution has been slow, functional, and continuous. We were shown some time ago a letter from an eminent palæontologist of America to a leading palæontologist of Great Britain. In it occurred the passage: "All we palæontologists of N. America are Lamarckists," and the writer added that he and his colleagues regarded Morgan's deductions with disgust. To quite similar conclusions our best living systematists have been driven. Prof. Elliot Smith, for example, in giving a fascinating account to a scientific society of the evolution of the human brain, showed how change of habit (function) and change of structure had gone hand in hand; he stated that he had debated the question whether change of habit or change of function had come first, and found that the only tenable supposition was that change of habit had come first, and that change of structure had followed.

We are gradually coming within sight of finding the causes for Morgan's mutations. They seem to be due to a disharmony of growth associated with a weakened vital energy. That the different organs of the body have independent powers of growth has long been known; that the growth of one organ influences and governs the growth of the others is also known. An organism may be compared to a dog-team, where the pace of all the dogs is regulated so as to lead to an harmonious result. When, however, one dog trips or falls or lags behind, irregularity results which manifests itself in abnormal pathological growth, and this is a Mendelising mutation. Its ultimate cause appears to be the weakening of vital energy caused by the withdrawal of oxygen at a critical period of growth; but this weakness once produced is handed on to subsequent generations. As the mutants are all afflicted with this weakness, they are all in a state of nature wiped out by natural selection, and play no part whatever in the process of evolution.

At the risk of being tedious we must reiterate that there is a growing body of evidence that the effects of the habits of one generation are handed on to the next, and in this principle we find not only the key to the explanation of the recapitulatory principle in life-history, but to that of the evolutionary process in general. After all as a leading English Mendelian has put it in the last resort variations are either due to chance or to the reaction of the animal to the environment, and between two such alternatives, what scientific man can hesitate?

EVOLUTION IN SPIDERS

AN ESSAY IN PHYLOGENY

BY THEODORE H. SAVORY, B.A.

THE courses of Evolution within the order Araneæ is a branch of the study of spiders which has been curiously neglected. Yet as material in which to trace the workings of an evolutionary tendency, spiders are particularly suitable, for various reasons.

In the first place, spiders as a whole form a fairly homogeneous group, and the differences of structure between the primitive and specialised types are not great. The thousands of species and hundreds of genera of spiders therefore provide a dense population within a small compass ; whence it follows that there must be a better chance of following the direction taken in evolution and a smaller chance of finding gaps, faults and breaks in the chain, with the uncertainties that result and the unconvincing search for missing links that follows.

Secondly, although the structure is homogeneous, the habits of spiders are diverse. Evolutionists as a whole are wont to base their hypotheses on the facts of morphology alone and scarcely to take heed of those of habits and instinct. Prof. E. W. MacBride has, however, recently emphasised the importance of the habits of the individual as a factor in evolution. It is certain that we shall do well to consider them, for there is bound to be a correlation between habits and structure, whether the structure be acquired in response to the habit or the habit result from the use of a structure which appeared suddenly as a mutation.

The habits of spiders are more particularly worthy of study, both because of their diversity and because of the existence of the spider's web. A spider's web is an almost unique structure in the whole animal kingdom, since the spider is, save one, the larva of the caddis *Hydropsyche*, the only creature that builds a trap in which to ensnare its prey. Hence the web may be regarded as a material expression of certain " instincts " or inherited characteristics of the central nervous system, and one, moreover, which affords an opportunity for architectural analysis.

Thirdly, ending this preamble, the order Araneæ is fortunate in the possession of the primitive genus *Liphistius*, and its close allies, living samples of the primitive spider and strikingly similar to the fossil spiders of the Carboniferous Era.

I have recently (*A.M.N.H.*, **9**, x, 1922, p. 444) dealt fully with the biology of these spiders from the point of view of the study of primitive animals and have adduced sufficient evidence from facts of anatomy, geology and geography, to prove their primitive character without doubt.

The first suggestion of evolutionary relationships between the different families of spiders was made by Thorell (*On European Spiders*, 1869). In the table on Plate I of his book, Thorell gives a diagrammatic representation of the tracks of evolutionary progress, in which he makes the Tubitelariæ the lowest group, with the Liphistioidæ one of several offshoots therefrom. It seems, however, to me abundantly clear that the Liphistioidæ must be the starting point.

The authoritative work on the world's spiders to-day is the *Histoire Naturelle des Araignées*, which we owe to the industry and genius of the late M. Eugene Simon. In the introduction to each of its thirty-eight families Simon puts forward the views both of himself and others as to the inter-relations of that family and those most closely allied to it. If one takes stock of all these statements, one receives the impression of a direct linear ascent from the lowest to the highest family, with many convenient intermediate forms, but withal plenty of room for divergence of opinion and an abundance of fog about the whole.

This suggestion of a ladder-like ascent, or "end-on" evolution from one family to the next above, is most to be deprecated. It separates far too widely the first family from the last, and it is not in accordance with the generally accepted views of the process of Organic Evolution.

By far the most important contribution to our subject is a small paper, "On Families of Spiders" (*Ann. N.Y. Acad. Sci.*, xxix, 145–180), by Prof. Alex. Petrunkevitch. It would be difficult to over-estimate the value and interest of this paper to araneologists, to whom it offers a view of spider-families far superior to anything they could obtain before. But I believe that it is now possible to carry the arguments a stage further than Petrunkevitch has done.

All will readily agree with Petrunkevitch in dividing spiders into three sub-orders, Mygalomorphæ, Arachnomorphæ and Liphistiomorphæ. These sub-orders may be taken as representing parallel and independent lines of evolution, indeed Petrunkevitch himself makes no attempt to find a relation between them

We are naturally concerned first with the sub-order to which Petrunkevitch has given the name Liphistiomorphæ. It is important to remember that *Liphistius* is not the ancestral aranead, but only the nearest living approach to such a primitive spider. It has undoubted specialised features of its own, for no primitive creature in any order of the animal kingdom is likely to be able to live for geological ages and retain unmodified its primæval form.

The habits of *Liphistius* were not until recently at all well known. Two new species, *Liphistius batuensis* Abraham and *Liphistius malayanus* Abraham, have, however, lately been added to the genus by Mr. H. C. Abraham, and their mode of life described. They spin tubular nests, similar to those of the more familiar trap-door spiders, the tubes either in burrows in the ground or hung upon the walls of caves. The silken tube is closed with a trap-door and its mouth is stayed by a number of radiating threads. In a photograph of such a web (*P.Z.S.*, December 1922, p. 769) its resemblance to the tube made by *Segestria florentina* Ross is obvious. I have already (*A.M.N.H.*, 9, xiii, 1924, p. 472) dealt more fully with this similarity, and have tried to show that it points to a hitherto unrealised relationship between *Liphistius* and the Dysderidæ, while at the same time the existence of dorsal sclerites of chitin on the abdomen of certain Oonopidæ, relating this family too to *Liphistius*, brings the three families into direct connection.

For this view I have received some friendly criticism, pointing out that a tubular retreat with a divergent mouth supported by radiating threads is a common type of web and that too much trust cannot be placed in such evidence.

I shall deal with the forms of webs in what follows, and I still believe that the form of the web is valuable evidence of the evolutionary track. I may, in support, refer to the words of M. Simon in the Introduction to the *Histoire Naturelle des Araignées*. Speaking of the advantages which he gained from collecting foreign species, he says : " C'est en voyant les grandes toiles en nappe pourvues d'une retraite tubiforme des *Hippassa* et des *Podophthalma*, que nous avons compris l'étroite parenté des *Agelenides* et des *Lycosides* qui nous aurait sans doute toujours échappé si nous avions restreint nos recherches à la faune de France." It is just as true to say that the relationship would have escaped him had he confined his attention to the morphology of the spider and neglected the architecture of the web.

We are now in a position to indicate the beginning of our evolutionary scheme.

The hypothetical arche-aranead had probably eight eyes fairly close together, four lungs, three claws to its tarsi, eight spinnerettes and twelve abdominal segments. It was a huntsman, but lived in a tubular silk nest, most likely without a trap-door. From this beginning, evolution has proceeded on three different routes, in all of which the posterior abdominal segments have been lost, only the anal tubercle remaining to recall their existence. The first and shortest of these three paths ends in the modern Liphistiidæ and the second belongs to the sub-order Mygalomorphæ, popularly the Trap-door Spiders. The third and largest is occupied by the sub-order Arachnomorphæ, of which the familiar Dysderidæ and Oonopidæ and their allies are in the most direct line from the primitive arche-aranead and most comparable to the Liphistiidæ. These two latter branches must be considered in greater detail.

The Mygalomorphæ, which yield themselves the more readily to analysis, have been dealt with by Petrunkevitch in the paper already mentioned. It is clear that changes in form and habits have developed in two different directions. Some specialised in digging and the building of nests with trap-doors. These acquired the rake or rastellum on the cheliceræ and shed much of their hair. Others became wanderers, growing a thicker coating of protective hair and losing the third or lower tarsal claw.

This last feature is of great importance when discussing the sub-order Arachnomorphæ, for it gives us a fundamental characteristic on which to base our divisions and serves to distract our attention from the cribellum.

Simon, as is well known, divided his Araneæ Veræ into two sections according to the presence or absence of this spinning organ. This implies, if our classification is to deserve the adjective "natural," that these sections represent different roads in evolution.

But so close is the resemblance between many families of cribellate and ecribellate genera that such a view cannot be seriously maintained. Nor are the resemblances to be ascribed to convergence. The cribellum, like the third claw, is an ancestral and fundamental possession, and from the original cribellated spiders time has produced both new cribellated and, the cribellum becoming the colulus, also new ecribellated families. And, of course, the latter have produced more ecribellated forms.

It might even be justifiable in some cases to unite both cribellate and ecribellate genera in the same family. The matter is really of small importance and chiefly one of individual opinion. Probably it is more convenient always to separate them.

Adopting this point of view, we find three or possibly four lines of evolution among the Arachnomorphæ. Since this sub-order is of chief interest to British readers, as well as the dominant one of spiders throughout the world, I shall take it in greater detail.

One well-defined group of families is that which, as already noted, lies in the most direct line from the *Liphistius*-like ancestor, and includes, of families represented in Britain, the Oonopidæ, Dysderidæ, and Sicariidæ. These are the families which, as I tried to show in the paper mentioned above, have adopted other methods of combating the dangers and difficulties of life than the construction of a trap-door to the nest. Since the rest of the sub-order may be regarded as derived from them, an explanation is afforded of the complete absence of the trap-door nests therein, although they are conspicuous in the other two sub-orders of spiders.

It will be noticed, too, that these are the families whose British species have six eyes—the old tribe Senoculina of John Blackwall. There are also common peculiarities about the respiratory system.

The remaining families divide themselves naturally into those with three claws and those with two.

The latter division includes, among British species, the families Clubionidæ, Drassidæ, Sparassidæ, Thomisidæ, and Salticidæ. These are practically all huntsmen who spin no web, and, as we have already seen, such spiders usually drop the inferior tarsal claws. On the tarsi of the spiderlings in the cocoon, however, the full complement of three claws is present.

There is, of course, a considerable difference of mode of life within this division. The most primitive families are the Drassidæ and Clubionidæ; indeed the latter includes *Corinna*, which spins the primitive divergent-tube type of web.

The Thomisidæ or Crab Spiders show the peculiarity of laterigrade movements and the Salticidæ have developed the habit of leaping upon their prey rather than running it down.

By far the greatest number of living spiders, however, possess three claws throughout their lives. The thirteen families of British spiders which belong to this division include representatives of all the four groups into which it is divisible.

First, the lowest group is certainly that which includes the Amaurobiidæ and the Agelenidæ. The familiar blue webs of the former are undoubtedly the cribellate analogue of the primitive divergent-tube. The corresponding web among the Agelenidæ is found in the genus *Cælotes* and its allies, while the other genera have hit upon the plan of extending the lower edge of the tube mouth into a large sheet, which must of course be stayed among the herbage with guy ropes above and below. This is the web of *Agelena*, and the ordinary indoor " cobweb " of *Tegenaria*.

Secondly we have a group of families, either parallel to the above, or perhaps derived from it, who have, like the two-clawed division, abandoned the web as a means of catching their insect-food. In Britain these are the Lycosidæ and Pisauridæ, the Wolf Spiders, and Oxyopidæ. The evidence of relationship between the Lycosidæ and the Agelenidæ has been mentioned above, and the facts of morphology do not fail to support this view. The Pisauridæ, as a matter of fact, are the most fundamental family and the Lycosidæ a later off-shoot from the same stock. Neither Lycosidæ nor Agelenidæ are, actually, closely allied to the Clubionidæ and the resemblances between them, which Simon mentions, are due only to convergence.

The third group consists, among British spiders, of the families Dictynidæ, Theridiidæ, Pholcidæ, and Linyphiidæ. It is clear that they represent descendants of the Agelenidæ group who have taken to a more arboreal life, up among the higher branches of the shrubs and trees.

Thus the Dictynidæ would represent the arboreal descendants of the Amaurobiidæ, two cribellated families which have previously been united into one.

If from the Agelenid web we were to remove the tubular part, for which in the more exposed situations there would be no protected site, and if we, therefore, install the spider under the sheet, the product is a Linyphiid.

If we remove both tube and sheet and leave only the stays which stretched, tangled, above and below it, the product is the web of the Theridiidæ. The Theridiidæ may well have been later in origin than the Linyphiidæ. The latter have been more successful since, especially the sub-family Erigonales (Hull), who took the new webs back to the old situations nearer the ground. But there is no doubt as to the close relationship between the two families.

The fourth and last group is much the hardest to place satisfactorily. It includes the families Mimetidæ, Uloboridæ and Epeiridæ, and it seems impossible to derive it at all directly from either Amaurobiidæ or Agelenidæ. It is best regarded as an early off-shoot from the third group, with whose later families its own are closely parallel. There are obvious similarities between the Dictynidæ and Uloboridæ, two cribellate families which both have claims to a genus *Æbutina*. The Mimetidæ recall the Theridiidæ in several respects, while the relation between the Epeiridæ and Linyphiidæ is so obvious that Simon classified them together in one family, Argiopidæ.

Epeiridæ, however, spin the characteristic orbicular web, which is made by no other family. How did this remarkable structure originate? It is a pretty problem and as yet unsolved. Could we arrive at a trustworthy idea of its origin we might be better able to judge the relation between our third and fourth groups of families in the three-clawed division.

THE IMPORTANCE OF MOSQUITO-CONTROL[1]

By SIR RONALD ROSS, K.C.B., K.C.M.G., F.R.S.
Director-in-Chief, Ross Institute and Hospital for Tropical Diseases, London

SIR RICHARD GREGORY, MR. MARSHALL, MEMBERS OF THE BRITISH ASSOCIATION, LADIES AND GENTLEMEN,

I esteem it to be an honour and a privilege that I should have been invited to open to-day a scientific institution of a somewhat novel scope, that is, one which has been designed, not primarily for teaching nor even, primarily, for investigation, but directly from a utilitarian motive. During the last five years many of us now present must have followed with interest the efforts of the founder, Mr. John Frederick Marshall, M.A., F.L.S., F.E.S., to deal with what appears to be at first sight—if not at the first experience of it—a wholly insignificant creature, the local gnat or mosquito.

Mr. Marshall came to reside in these parts in 1908, and, like many who live in the so-called sunny south, soon had his attention drawn to those indefatigable tax-collectors of our blood itself—the insects mentioned. Gradually, it seemed to him, their requisitions became more and more frequent ; and when, during the war and owing to the scarcity of labour, the local water-channels tended to be choked up, these mosquitoes ended by being quite a serious pest. I remember that as recently as three years ago, when I was visiting Mr. Marshall here, I was at first rather sceptical regarding their alleged attacks—until he took me into a sheltered part of his garden, where I at once saw several *Ochlerotatus detritus* flying about in broad daylight before my eyes. While I was observing these tiny monoplanes with interest, my host remarked that three of them were simultaneously engaged in abstracting blood from the back of my neck! Indeed, I have seldom had such an experience even in India or West Africa. At that time Mr. Marshall was already commencing his campaign against the plague. In 1920 Dr. C. G. Lamb, of Cambridge University, had put him in communication with Mr. F. W.

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[1] **Being the Opening Address for the British Mosquito-Control Institute, Hayling Island, Hants, delivered on Monday, August 31, 1925.**

Edwards, of the British Museum, who predicted that the chief pests concerned were likely to be *Ochlerotatus detritus* and *Ochlerotatus caspius*—which proved to be the case as regards the former. Mr. Edwards lectured in Hayling Island in April 1921, and next day a committee of local residents was formed to organise a scheme of control. They called themselves the "Hayling Mosquito Control," with Mr. Marshall as Honorary Director. Early in the same summer the larvæ were discovered in stagnant salt-water pools about a mile and a half distant from the residential quarter, and these were kept oiled at first and abolished, more or less slowly, as soon as permission was granted by the landowners and the necessary funds were available (Mr. Marshall refused to explain whence most of these moneys were derived). It was remarkable how far the insects travelled in spite of the fact that they had fine fresh tripper food close at hand—I saw some boys with their faces covered with bites, and mention the point because it is always said, after a successful mosquito-reduction campaign, that there had never been any mosquitoes at all in the locality concerned.

This preliminary work was described and illustrated in *Health*, of November 5, 1921, and in SCIENCE PROGRESS, of January 1922; and the former publication attracted the attention of the Ministry of Health, which deputed Colonel S. P. James to visit the spot and to make inquiries; with the results that the Ministry later contributed a grant of £100 for further work, while Colonel James, whose Indian labours in this line are well known, rendered help in many ways out of his large experience, and lent the services of Mr. P. G. Shute, his assistant at the Ministry, on a number of occasions in 1922–3. It is pleasing to record that the Havant Rural District Council has also contributed three annual sums of £75 towards the expenses of the labour required for surface-drainage. The residents of Hayling Island have added about £200 to these funds. In 1922 Sir Richard Gregory (Editor of *Nature*), who resides in the Island and has shown great interest in the subject, became Chairman of the General Purposes Committee, which consists of Mr. G. M. Fletcher, Dr. A. J. May, Mr. L. V. Turner, besides Mr. Marshall—to all of whom warm thanks are due for their help. A number of collectors have also done useful work, especially Messrs. W. G. Worsfold, D. Wilson, and J. Staley; and Mr. H. J. Earney, Head Master of Hayling Church of England School, has taken much trouble in organising and instructing a "mosquito-control class" of school-children, whose youthful eyes have often proved to be more penetrating than those of their elders. All the work actually achieved has been fully described in a series of four admirable annual Reports of the Hayling Mosquito Control published in June each year. It has always been a difficult task to measure the numbers of mosquitoes in any locality, and *Ochlerotatus detritus* is peculiarly refractory in this respect because it refuses to enter traps and houses. Apparently, therefore, the only way to estimate changes in the numbers of these insects has been the old method of recording a " census of opinion " on the subject among local residents. The results have been very satisfactory. Out of 125 householders who have been here for more than two years and who replied to the questionnaire, 115 or 92 per cent. stated that the nuisance had " much decreased " ; 10 or 8 per cent. admitted that it had " decreased " ; while none claimed that the numbers had actually increased. This last was a fortunate result for Mr. Marshall, for once, in West Africa, when we had cleared a house of every mosquito, the householder maintained that we had introduced them for the first time ! Any way, it can be safely claimed that a great reduction in the number of the insects here has been actually made. More than this, the habits of *Ochlerotatus detritus* and of other local species, as well as the insects themselves, and the best means for reducing them, have been very carefully studied, figured, and described, and a number of breeding places have been permanently abolished, while many others have been temporarily treated.

Towards the end of last year the work was becoming so extensive and interesting that Mr. Marshall thought of establishing a special Institute in connection with it ; and we are here now to view the result and to commemorate the occasion. Again he refuses, most unreasonably, to explain how the necessary funds arrived, and we can only suppose that some genie out of the *Arabian Nights* takes an interest in mosquito-control—I wish the rest of us could capture similar genii equally easily. As you will all be able to see, this new house contains a demonstration museum, a laboratory, a drawing and record office, a photographic room, and a mechanical workshop, all on the ground-floor. On the first floor there are a committee room and four other rooms, which will be used as required, as, for instance, by any research-workers who may wish to avail themselves of the opportunities here given. In the gardens there are numerous shady and sheltered groves in which the *Ochlerotatus* formerly abounded and where any of you, who desire to do so, may offer yourselves as a sacrifice to these voracious insects—if there are still any to be found here. I should like to call the attention of the numerous learned bodies which grant scholarships for scientific research to the facilities for it now obtainable here ; and I hope that the new Institute will shortly be humming like a hive of scientific labourers.

Whatever the future may hold, I am sure you will agree with me, that all this work just described has been a very meritorious adventure. The benefit of it is by no means confined to Hayling Island. Here mosquitoes cause only *annoyance* to residents and to visitors during the summer; but in most tropical countries they also carry formidable *diseases*; and in some they are positively the enemies of the human race. Now any knowledge gained regarding one variety of mosquito tends to help us in gaining knowledge regarding other species; and I have, therefore, no doubt whatever that the British Mosquito-Control Institute is destined to play its part in a much wider war than that suggested by its name. As Mr. Marshall said at the meeting of the British Association at Southampton last Thursday (August 27), the subject of "mosquito-control" contains three divisions: first, the general life-history of mosquitoes; secondly, the particular life-history and classification of each species (of which there are 25 in this country, and no less than about 1,400 species already known in other parts of the world); and, thirdly, the best methods for controlling each local species. The study of mosquitoes has already become a voluminous branch of science. When I commenced my work on malaria and mosquitoes in India, thirty years ago, I could not obtain a single book, nor even a single good article, on the mosquitoes of that great country. Now there are a number of laborious, but still far from exhaustive, textbooks devoted to the study of these insects, beginning with the classical book in six volumes by Mr. F. V. Theobald (who we all regret cannot be here to-day), on the *Mosquitoes of the World*, written on behalf of the Colonial Office and the Royal Society and published from 1900 to 1911; and the more specialised books or papers by Giles, James, Howard, Alcock, Lang, Wesenberg-Lund, and others—altogether a most admirable contribution to the world's welfare (for which, I may add, none of the authors has received, in my opinion, any adequate reward).

At present, then, we possess much knowledge of the subject. But the world always requires something more than knowledge, and that is the energy to act upon knowledge. We must now try, after a quarter of a century of investigations, to make more serious efforts against these disease-bearing enemies of mankind. The work done in Ismailia, Panama, the Federated Malay States, and elsewhere has been only a beginning. Our ultimate aim is to control, not only mosquitoes, but all the dangerous, or even the unpleasant, pests which affect us and our crops and herds everywhere. A far ideal perhaps, but one which is quite possibly within easier reach than we now imagine. We never know what surprising progeny Science may not bring forth;

and he is rash indeed who would prescribe limits to her victories. Many observations which appeared quite trivial at first have now given us immense new continents of knowledge. When Columbus first sighted a small island of the West Indies he thought merely that he had found a new route to China—he had really discovered a New World. One often wonders what the great philosophers of ancient Greece would think and say if they could behold our progress of to-day. *They* were obliged to walk or to ride over their little country : *we* can now traverse it through the air in an hour or two. *Their* poets and orators addressed them only within earshot : *we* can now listen to symphonies performed hundreds or thousands of miles distant, and can read the world's news of yesterday in our newspapers every morning. So, also, I have little doubt that the great diseases which still oppress us or destroy us by millions will some day fall into our power, or, indeed, be entirely banished from among us. Even if this be too optimistic a hope, yet we shall do well at least to reach towards it. It is ridiculous that mankind. who have extended their dominion over the earth, the sea, and the air, should continue to be prey of bacilli, and should even die of such contemptible things as colds in the head and mosquito-bites !

But in order to enlarge our dominion over these small, but deadly enemies, we must begin by enlarging our ambition. We must no longer be content to sit and sneeze with our feet in hot water, or to provide Lord Mayors' banquets to *Ochlerotatus*, or to lie down and die in the presence of a micrococcus one ten-thousandth part of an inch in diameter. What mean creatures we must be if we are to be conquered by such mean things as these ! Yet this is almost exactly our position to-day. It is true that during the last eighty years the average length of human life in this country has been prolonged by about fifty per cent., chiefly by means of improved medical and sanitary science and administration ; but we still die of many diseases which will probably be conquered some day. Why not accelerate the progress of this science by all the means in our power ? As I have often pointed out, we in this country are now spending only a small sum on medical research, apart from education, hospitals, and ancillary services. I estimate that each Briton is now giving, for medical research, on the average as much as one penny a head once a year ! Think of it—what generosity for matters of life and death, regarding ourselves, our children, and the whole nation ! To supplement this paltry sum, instead of putting our own hands in our own pockets, we call upon private philanthropists like Mr. Marshall to help us. A single bottle of whisky or a single leg of mutton costs us twelve times twelve times as much as each of us now spends on medical research during a whole year. I always maintain that the people of this country would be wise to lay out at least one million pounds a year on medical research alone, instead of one-fifth of that sum which they give at present. Even one million pounds a year would be trivial compared with the money which we now spend on alcohol, tobacco, and entertainments—not to mention education, armaments, and doles. After all, our health and our lives are, perhaps, the most important matters which concern us.

But, as I have already said, the object of this fine new Institute is, primarily, not medical but general—though I have no doubt that it will always keep the sanitary applications of mosquito-control always within range of its vision, if only upon its horizon. In all directions, knowledge dovetails in with other knowledge. Mosquito-control here will facilitate mosquito-control in the most pestiferous regions of the earth ; and the day may come—indeed, I am sure that it will come—when all those fertile tracts of the world which are now dominated and ravaged by King Malaria and King Mosquito will be laid open to civilisation. But this happy result will only be attained by more thought, by more research, and by a firmer determination to make the most of the beautiful world in which we live.

In the past, nearly all scientific discoveries, like the masterpieces of literature, have been free gifts bestowed by private individuals upon the whole of humanity, not only of to-day but also of the future. Let us then, at least, give our thanks to those who endeavour to assist the footsteps of progress towards any higher ideal and wider perspective.

I have great pleasure in declaring the British Mosquito-Control Institute now open ; and should add that it has found favour in the eyes of that august body, the Ministry of Health, and is ready to advise anyone whose house is suffering from the mosquito-plague and who will write to the Director on the subject. I wish the Institute every possible success in the future, and venture to suggest as a motto for it the words *Pax et Labor.*

POPULAR SCIENCE

THE POST-ROMAN HISTORY OF THE RHONE DELTA

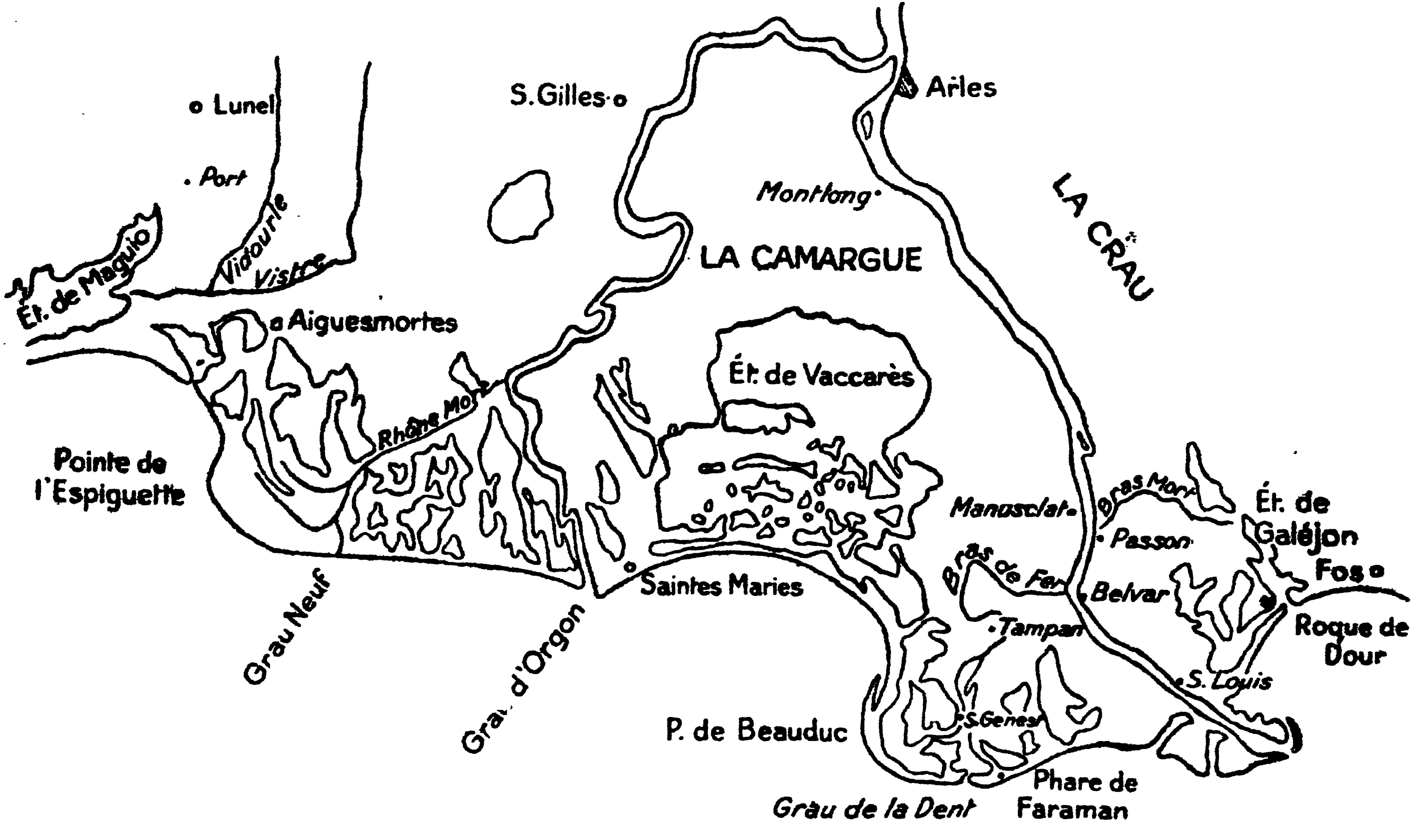
By R. D. OLDHAM, F.R.S.

If a map of the delta region of the Rhone Valley is examined, it will be seen that, just above the town of Arles, the river divides into two branches, the eastern flowing southwards, in a nearly direct channel, to the sea, while the western flows past St. Gilles, to enter the sea just west of the village and shrine of the Saintes Maries. Between these two branches of the river lies the region known as the Camargue. Along the banks the ground is high, fertile, and dotted with farmsteads, away from the river bank the level drops to extensive salt marshes and lagoons, and in the centre of the region is a vast salt lake, the Étang de Vaccarès, cut off from the sea by a narrow band of beach and sand-dunes. Seen on a map, and especially on a small-scale map, the region, as a whole, presents so many of the characters of an immature delta that it has been almost universally accepted as such by geologists, engineers, and archæologists, who with one accord supposed that there has been a continuous and uninterrupted growth of the delta, which was much smaller in size, during the Roman domination of the country, than it now is. Yet there have always been difficulties in this interpretation of the facts.

Though the general distribution of the surface levels is as has been described, there are places, remote from the river channel, where the ground rises well above the highest level ever reached by the floods of the river, and there have been interpreted as the remains of successive coastal barriers, formed on the face of the advancing delta. In some cases the nature of the soil suggests that these elevated tracts are the remains of old sand-dunes, but in many others there is no such distinction from the ordinary material of which the rest of the delta is composed. There is also the positive evidence of occupation, during the Roman period, at places close to the existing shore line. At Saintes Maries, for instance, now and for centuries a celebrated place of pilgrimage, inscribed stones have been dug up, which, accepted by competent scholars as genuine relics of the Roman period, show that the site was not only inhabited, but a place of pilgrimage and devotion, in pagan times. Farther east, at a place about three kilometres west of the Vieux Rhone, and within two of the sea coast, a stone was found, in 1883, bearing a Latin inscription indicating that it was erected near the course of the Rhone ; the character of the lettering has led to its being regarded as of the fifth or sixth century, and, for other reasons, it cannot be of much later date, but in any case it proves that the spot where it was found must have been dry land at the time when it was carved and set up.

These instances would, by themselves, be enough to show that the delta was at least as extensive, in Roman times, as it now is, but of the detailed geography we know very little. The ancient geographers differed in the number of separate mouths which they ascribed to the river, some making them as many as nine ; but, in a deltaic river, there are always a number of channels leading to the sea, the number and position of which are continually altering, as some get closed by river silt and others open up, and, since these channels vary much in size, the number of mouths of such a river depends on what the enumerator chooses to class as a mouth. There were, however, evidently three main channels to the sea, the western one was known as the Spanish, and was the mouth of a channel which, quite possibly, flowed down to, or through, what is now the Étang de Mauguio ; the easternmost was the largest of the three, and known as the Massilian ; the third lay between these two and, according to Pliny, was called Metapine, but whether the divarication leading to it took off from the main stream, or the western channel, cannot be said.

Of the position of the two western mouths nothing positive is known, but as regards the eastern, or principal, we have some fairly definite information. In the early centuries of our era there arose, at or near the present village of Fos, a seaport known as Fossæ Marianæ, which rose to great importance, though there was no country behind it but the barren, stony tract of almost desert land known as the Crau ; yet the port served an important purpose, as a port of destination for the sea-going ships which were then, as now, unable to enter the Rhone, and of departure for the smaller vessels, capable of crossing the bar and navigating the river, which was the principal, and almost the sole, trade route into the interior of the Gallic region, rapidly increasing in wealth and population. From this port to the Massilian mouth of the Rhone, the distance, according to the maritime itinerary, was 16 Roman miles, and from the mouth was 30 miles by


Arles
S.Gilles
o Lunel
Port
Vidourle
Vistre
Ét. de Maguio
Aiguesmortes
Montlong
LA CAMARGUE
LA CRAU
Ét. de Vaccarès
Rhône Mort
Pointe de
l'Espiguette
Grau Neuf
Grau d'Orgon
Saintes Maries
Manosclat
Bras Mort
Passon
Ét. de
Galéjon
Fos
Bras de Fer
Belvar
Tampan
Roque de
Dour
S. Louis
S. Genest
P. de Beauduc
Phare de
Faraman
Grau de la Dent

32

river to the city of Arles. These distances place the mouth not far from the present position of the Grau de la Dent, just west of the Faraman lighthouse; as the distances in the itinerary are only approximate it is not possible to fix the position exactly, but it is, at least, clear that the mouth of the main stream lay farther west than the places at which the present river enters the sea.

Of the country inland we have but little detailed information. Arles was a city absolutely, and to a greater degree relatively, much larger and more important than it now is; it was the most important town in Gaul, and in the time of Constantine the Great and his immediate successors possessed an imperial palace, which was repeatedly occupied by the Emperor. Just above Arles the river, as it still does, divided into two branches, and the Camargue, now, with some local and limited exceptions, almost uninhabited, with vast stretches of pasture and salt marsh over which roam herds of more than half-wild cattle, horses, sheep, and goats, and where the sense of solitude is described as more impressive than on the ocean itself, was described, in Roman times, as the granary and store of the Roman Army, a description confirmed by the numerous remains of old settlements which are found scattered over it.

These conditions seemed to have continued even after the barbarian invasions had put a term to the Roman empire over this country. The entry to the river was still difficult, and practicable only for boats of very shallow draft, and the port of Fossæ continued an important one, trading with the most distant shores of the Mediterranean and receiving the products of those countries, as well as the spices and drugs of the distant Orient. This continued till the year 716, and possibly later, for shortly after, in 730, came the Saracen invasion, the country was devastated, and the Dark Ages supervened, in which little or no record was kept, or if kept has perished almost completely. Almost the only geographical information which can be gleaned is in a charter of the early part of the tenth century, which implies that sea-going vessels from Greece and other countries were in the habit of visiting the port of Arles.

With the twelfth century, information again is to be gathered. Considering the lapse of time, and the vicissitudes which the country has gone through, we can form a remarkably good idea of the condition of the eastern half of the delta at that time, and the picture developed is notably different from that which the records of the Roman period convey, as also it is from existing conditions. The earliest account is that of Gervase of Tilbury, who wrote, in 1211, his *Otia Imperialia*, which describes the region, of the Rhone delta, as bordered with islands along the sea face, and, in a shrewd characterisation of the people of Arles, he mentions that they were skilled and victorious in naval war. This, as the charter just mentioned, shows that sea-going vessels of the class then in use could easily reach Arles from the sea, and other records prove that the channel of access was not by the river mouth of Roman times nor by the existing entrance and channel, but by the Etang de Galéjon, past a low hill called the Roque de Dour or, more briefly, la Roque, which appears on the portolan maps of the Middle Ages as Odor, and in the *Historia Major* of Matthew Paris as Roka. From the Etang de Galéjon, the channel led, over what has now been converted into land by the alluvial deposits of the Rhone, to the village of Passon, and thence, along the main stream of the river, to Arles. This channel we know, from other sources, to have carried at least 8 feet depth of water, sufficient to admit the vessels of 100 to 150 tons burden, on which a large, if not the greater part, of the commerce of those days was carried.

This state of affairs, so different from that which prevailed up to about 500 years before, offers a problem which, till quite recent times, was insoluble. The later history of the delta, since the end of the twelfth century, offers less difficulty, but the change which took place during the Dark Ages, and the contrast revealed between what we know of the conditions up to the end of the seventh century, and that which we find when light first dawns in the twelfth, is less easy of understanding. Only within the last three years has the real clue been found in the geological work of G. Denizot,[1] on the alluvium of the delta of the Rhone. He finds that, besides the modern alluvium, which is evidently a recent product of the river under conditions similar to those still existing, there is an older alluvium which rises to heights, in places, of as much as 5 metres above sea level, and exposes an undulating surface, worn, by rain and weather, from a deposit which must once have reached a higher level than the existing surface. This alluvium could not have been formed by the river in circumstances as they are at present, for it contains banks of cockle and other sea-shells, which must have lived, died, and been entombed below sea level, but are now found at heights up to a metre or more above the highest level reached by the existing sea. There must, consequently, have been a change of level, of the land relative to the sea, since these deposits were laid down. This conclusion is confirmed and established by the discovery, and the date of this uplift, though geologically very recent, must have been earlier than the time of the arrival

[1] G. Denizot, "Contributions à l'étude du Quaternaire de France," *Bull. Soc. Geol., France*, xxiii, 1924, pp. 384–430.

of the Romans in this country, for it is on the gently undulating surface, worn out of the old deposits, that remains of Roman settlements are found.

This uplift was not, however, the last change of level, for there has been a move in the opposite direction, a subsidence of the land or a rise of sea level, which can be dated with certainty as later than Roman times. This subsidence of the land was first brought into prominence by Dr. R. T. Gunther by his studies of the district near Naples, and since then has been recognised at a number of other places round the coast of the Mediterranean, and everywhere can be dated, as having taken place in what are known as the Dark Ages, between the end of the Roman period and commencement of the Middle Ages. The region near the Rhone is no exception ; M. Denizot finds definite proof of a post-Roman subsidence in the neighbourhood of Fos, and, though he cannot find geological evidence for a change of more than a part of a metre, this evidence does not exclude the possibility of a greater change of level.

The effect of this subsidence is still visible in parts of the delta ; the great expanse of salt water in the centre of the delta, known as the Étang de Vaccarès, though it appears from its position and form, as seen on a small-scale map, to be one of those shallow meres which are common in alluvial plains, takes on a very different aspect when examined on the spot, or on the *état-major* map of the French Government. The pools left on an alluvial plain, which is in course of formation, have low, ill-defined banks, where the almost imperceptible slope of the surface gradually dips below the water level, and a change in level of the water by a few inches may shift the water's edge by hundreds of yards. The Vaccarès on the contrary has comparatively high banks, scarped in many places by the action of the waves, and these banks are formed of that older alluvium which was upraised and worn, by denudation, into an irregular surface, before it was depressed and submerged below sea level, over the region now occupied by the Étang. To the south of the expanse of open water, and separating it from the sea, is a stretch of shallow water studded with islands, called *radeaux* or rafts, mostly small, which have well-defined outlines, and in some cases rise to a considerable height above the water. These have been regarded as the remains of an old *cordon littoral*, or range of sand-dunes, and the interpretation seems borne out, in some cases at least, by the mineral composition of the ground ; but the disjointed character of the islets, separated by shallow, well-defined channels, is eloquent of subsidence, and M. Denizot, describing the surface features of the ground to the north of the Vaccarès, remarks that a subsidence of about a metre would convert this tract into a copy of the island-studded waters to the south. This remark may be reversed, and we may conclude that in Roman times, before the subsidence took place, this country was dry land, very like, in character and appearance, the high grounds to the north of the Étang de Vaccarès, as they now are. This sunken country, protected from the inundation of the river by a barrier of high ground rising above flood level, has preserved for us a picture of what was, for a time, the aspect of the whole sea face of the delta.

For a measure of the amount of this subsidence we must look elsewhere. As has been mentioned, the river, in Roman times, reached the sea face, and the entrance, as now, was obstructed by a bar, over which the passage cannot have been deeper than at present. When subsidence of the land took place, and a large part of the delta went under water, the actual river mouth issued into a sheltered inlet, where it was not exposed to the stormy seas, which play so large a part in producing the bar. For centuries there seems to have been no barrier, at the actual mouth of the river proper, to trouble the shipping, then in the habit of visiting Arles, but the statutes of that city prove that the channel was not without difficulty, for they lay down that outward-bound vessels which were detained by contrary winds *ad staccam vel ad morandum de passano* must place their boats and crew at the disposal of vessels inward bound. The words used are capable of a double interpretation and, as they may apply to land or water, may mean either the stockade and houses, or the pool and mooring place, of Passon ; in either case they prove that there was shallow water and difficult navigation near the village of Passon. This difficulty cannot have been a bar at the actual mouth of the river, for this did not reach Passon till about the middle of the fifteenth century, and the statute, though the actual date of promulgation is not known, was certainly older than 1245, in which year the body of then existing statutes was collected. The real character of the obstruction may be inferred when it is remembered that this channel did not exist in Roman times, and could only have been opened up by submergence of what was then dry land, the shallows of Passon representing the position of the *col* or highest ground along the course of the channel. A portolan, or book of sailing directions, evidently written in the early part of the fifteenth century though not printed till 1490, gives a description of this channel, and states that near Passon there is a depth of one and a half to two *passa* at most, and as the Venetian *passa* was about 5 feet 8⅜ inches, the depth may be put at 8 to 10 feet of our measurement, and hence the submergence must have been at least 10 feet, for it must have been equal to the original height of the land added to the original depth of water. As the land was almost certainly more than two feet above the sea level, and the water, in the absence of a strong current, would be continually shoaling, this figure, of 10 feet, is evidently a minimum estimate. The maximum can be obtained in another way.

The city of Arles, controlling the administration of the eastern part of the delta and the navigation of the Rhone to the sea, was in the habit of maintaining an armed and fortified post at some point down the river, for the double purpose of protecting its revenues, and of excluding raiders or other undesirable visitors. These purposes indicated a situation as remote as possible from the city, yet not so far off that any vessels could enter the main stream by an alternative channel, without passing the post. The changing conditions of the river made it necessary to alter the site from time to time, and we have a complete record of the successive moves, farther and farther down-stream, from the year 1469 onwards, but for earlier times the record is less complete, though there are indications that a similar post was maintained. The earliest of these is in connection with an excursion of a fleet of Genoese galleys in 1165, when it is recorded that they were met *prope Molendinos* by the consuls of Arles, who demanded whether they had come in friendship or enmity. The exact position of these windmills cannot be determined, but other records of the same period make it probable that they were on the western bank of the river a little below the hamlet of Montlong, a very suitable position for a post of observation and defence, as it lay just above the place where a channel branched off. This side channel is now silted up, but it was open and navigable in the twelfth century. At some later period, after this channel had ceased to be navigable, the post was moved down-stream to near Manusclat, a little above Passon, where it could control the traffic using not only the principal channel, but also the others which were open to navigation, though less used. The date at which this move was made is not known, but it is known that in 1469 the city decided to replace this post, which had ceased to be useful, by another, the Tour de Belvar or Bolovard, farther down-stream, at a point where it could control the traffic from the three separate entrances, which were then usable. This site lies at a distance of about four kilometres down-stream from Passon, and was, therefore, unable to control any traffic along the old channel which had been the principal one in the twelfth century. The obvious, and in fact the only, explanation of this change is that by 1469 the river proper, in the sense of a fresh-water stream flowing in a channel of its own formation, having reached Passon, flowed straight onwards, and blocked with silt the channel along which ships used to reach Arles. The later changes in the course of the Rhone from the sixteenth century to the present day are well known, have been repeatedly described, and do not particularly concern the matter under discussion. The earlier changes which are, unfortunately, less precisely known indicate that the post-Roman subsidence brought the sea level to the neighbourhood of, and perhaps actually to, the city of Arles.

The usual flood-water slope of a river in an alluvial delta of its own formation—and it is the flood-water slope which decides the general slope of the land surface of the delta—is about 1 in 10,000, sometimes gentler, usually a little steeper, but not varying much from this figure, equivalent to about 6 inches in a mile. The Rhone is no exception to this rule, and the ordinary high-water level at Arles is about 6 metres above the sea, which is distant some 50 kilometres, measured along the channel, and about 45 in a straight line, but the flood level at Arles is raised by the embankments which confine the river, on either side, all the way above Beaucaire to the sea ; if uncontrolled the level would be less, and probably not much, if at all, above 5 metres. As the sea face in Roman times was near its present line, the flood level of the river and of its alluvial plain near Arles would be about the same height above the sea as now, and so we get 15 feet as a possible maximum measure of the subsidence, for which a minimum of 12 feet has already been indicated.

The western branch of the river was affected by the subsidence equally with the eastern, and with equally remarkable results. A broad and shallow channel opened up from the Étang de Mauguio to beyond St. Gilles, and that town became a seaport, possibly only for vessels of smaller size than those which could reach Arles, but still of sea-going size and draught. The career of St. Gilles, as a seaport, closed with the twelfth century, by blockage of the entry, and the extension of the deposits of the Vistre and Vidourle to Aigues Mortes, where St. Louis established a new port in the thirteenth century. The impress of this old approach, from the sea to what is now the interior of the delta, is to be seen on the sea charts of the Middle Ages, the so-called Portolan maps, and not till the seventeenth century did it cease to figure on maps of this region,[1] but the most interesting point connected with this western approach is the fact that we can date the period of the subsidence.

At the eastern end of the present Étang de Mauguio, but now separated from its waters by about 3 miles of low, largely marshy, alluvial deposits, a farmstead called Mas Desports is marked on the French Government map. This is all that remains of a place which, in the ninth century, was a seaport, composed of two parishes, and of sufficient consideration to serve as the place of assembly of provincial synods, held in 887 and again in 897. If this place was a seaport, as its name and history imply, it must have dated from after the close of the subsidence, and so we can fix this last-named date as long enough before the year 887 to have enabled the place to become recognised as a port of destination.

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[1] R. D. Oldham, "The Portolan Maps of the Rhône Delta," *Geog. Journ.* lxv, 1925, pp. 403–424.

The main geological interest of this change of level lies in the fact that it can be dated as not having commenced in the year 716 and having been completed by the year 887. Probably it was confined within even narrower limits, but can hardly have been abrupt and cataclysmic, for a cataclysm of such extent and magnitude could hardly have occurred without leaving its impress on traditional, if not on contemporaneously written, history. The record, then, is of a long period, covering the whole of the Roman dominion and up to the eighth century, during which there seems to have been no appreciable change of level; next a period of at most a couple, and probably a single, century in which there was a gradual, but according to ordinary notions rapid, subsidence of 12 to 15 feet; and then another thousand years and more, during which there has been no appreciable change. Nor does the interest cease here, for the subsidence was, apparently, not confined to the delta of the Rhone; all along the coasts of the western Mediterranean, in Italy and on the African coast of Tunis, are repeated evidences of recent subsidence, and almost everywhere it can be dated as having occurred within the limits of, at the outside, the eighth and twelfth centuries. It is by no means improbable that it was everywhere contemporaneous with that of the region which has been dealt with here, and in general appears to have been about the same in amount. So widespread and uniform a change of relative level of land and sea opens out large and interesting fields of speculation as to the cause, but they still need a large amount of work before they can be reclaimed from that primitive condition, to yield a harvest of positive conclusion.

NOTES

Personal Recollections (Sir A. E. Shipley, G.B.E., F.R.S.)

(1) John Young Buchanan

The late J. Y. Buchanan, F.R.S., was born in Scotland, 81 years ago. He was son of John Buchanan, of Dowanhill, Scotland, and was educated at the High School in Glasgow, and at the University of that city. Latterly, he pursued his studies at Marburg, Leipzig, and Bonn, and at the École de Medécine, Paris, and thus it was that he acquired his remarkable facility for speaking foreign tongues.

He was essentially a Chemist, but a Chemist with a very wide outlook, and much of his work was mineralogical and physical. He was fortunately a member, as Chemist and Physicist, of the Staff of H.M.S. *Challenger*, which circumnavigated the world in the early seventies. What appeared at one time to be the most remarkable result of the best-equipped expedition that has ever explored the depths of the ocean, was the discovery of a glairy, viscid amorphous substance, very like the Myxomycetes, which cover large areas in the damp places of our woods. This substance seemed to have been spread all over the ocean bottom. This was for a time regarded as the primitive living substance, the origin of higher life, and Huxley christened it *Bathybius*, and took a keen interest in it, which, however, collapsed when Buchanan showed that the substance was really an amorphous form of sulphur, precipitated by the addition of sea-water to the alcohol in which the marine organisms were preserved. Huxley acknowledged that a mistake had been made and never referred to the subject again.

Buchanan wrote part of the two Narrative Volumes and the section on the Specific Gravity of Sea Water, published in the *Scientific Results of the Voyage of H.M.S. "Challenger,"* and, had he cared to, no doubt he might have taken an active share in editing the volumes after the death of Sir Wyville Thompson. But he was blessed with wealth and he preferred devoting himself to his researches, and indeed, in some respects, his wealth hindered the publication of much of the work which he had brought to fruition. He, not infrequently, achieved the stage where he himself was satisfied, but he did not always take the trouble to write his results out for presentation to the rest of the world. If everything he investigated had been published it would have shown an amazing range of scientific curiosity, satisfied but not made known.

Amongst other problems he was very keenly interested in the melting of ice and the formation of glaciers, and he used to spend part of each winter in Switzerland investigating these processes.

He was a brilliant conversationalist, original in his views, and full of quaint phrases and humorous recollections. From 1889 till 1893 he was Lecturer in Geography at the University of Cambridge, and when he resigned he continued to reside at Christ's College for many years. When he left, to live in London, the Combination Room of Christ's College lost one of its most brilliant members.

Buchanan was extremely generous and constantly presented costly books and other objects of value to the College, and he was always ready to help a deserving but impoverished student. A tall man, his fine presence and handsome face have been immortalised in a portrait, now hanging in the Master's Lodge, by Tinayre, a brother of the well-known French novelist, Marcelle Tinayre. It was, unfortunately, taken after a certain melancholy had settled on his soul, and that melancholy, if anything, has been over-emphasised by the artist.

Buchanan was an intensely patriotic Briton, and a very strong Tory. His mother was an equally strong Liberal, and being a very vigorous and commanding old lady she used from time to time to irritate Buchanan by inviting Home Rulers, such as Parnell, to her handsome house in Edinburgh. One of her other sons was M.P. for that City and Under-Secretary of State for India, under a Liberal Government.

J. Y., as his friends called him, had all a sailor's dislike for "gear," and his rooms were comfortably but very sparely furnished. He did not like to have too many things about him, and in the long run he gave up his comfortable house in Park Lane and took refuge in a small suite in a West End hotel, reducing his worldly possession to what could be held in a couple of trunks.

Buchanan had many acquaintances amongst the high-born on the Continent. He was a close personal friend of the Prince of Monaco and of the Grand Duke Carl Theodor, the father of the Queen of the Belgians. He used to visit the ex-Kaiser during the Kiel Week, and he was absolutely convinced that war was close at hand. When it broke out he was already an elderly man, and his feelings were such that he crossed the

Atlantic and spent the first winter of the war period in Cuba, and the next three winters in Boston, Massachusetts.

To those who knew him well, Buchanan was a close friend. He was jealous of his reputation as a man of science, and towards the end of his life he collected his published works under the titles of *Accounts Rendered* and *Comptes Rendus*. He had numerous friends and many acquaintances, but, like many a Scot, it was his friends who knew him intimately that really appreciated his great qualities of heart and brain, for he was, in a way, a reserved man and never wore his heart on his sleeve.

(2) JOHN NEWPORT LANGLEY

I first remember Langley over forty years ago. Under Michael Foster, he, Sheridan Lee, and Gaskell were the leading teachers in the School of Physiology in the early eighties. At that time Langley was lecturing to the advanced class, and his lectures were extraordinarily good, clear, and stimulating. It was a misfortune that on Michael Foster's death Langley carried on the tradition that the Professor should lecture to the elementary students, for as a lecturer his gift did not lie in the direction of interesting beginners in a subject. Either he expected them to know too much or his courses were not adapted to a large audience, but for some reason or other his elementary lectures had not the same success as those to which I and my contemporaries listened.

There was something very neat and dapper about Langley. His clear-cut face with his striking eyes helped to make up an impressing figure. He was a man you could not overlook in any assembly. He was always singularly young for his age, and to the very end (he was well over seventy) he used to bicycle from his home to the Laboratories. Perhaps his bodily activity kept him young, for he was a first-class tennis-player and used to be President of the Trinity College Lawn Tennis Club. He was also a brilliant skater and President of the University Skating Club. Latterly he spent much time in his garden, and used to be singularly successful especially with his tulips. Both at work and at play he was very strenuous. After he took over the *Journal of Physiology*, from Foster, he spent many hours a week in editing it and frequently he would rewrite whole pages of contributed MSS., and in every case it was recognised that he had effected great improvements and usually a marked degree of concentration. He was a good business man, and at a time after the War, when other Laboratories were losing money, he, with the help of Dr. Shore, managed to save annually a considerable sum, which he hoped ultimately to contribute to the cost of the Lecture Room, which was part of the original plan for the new Physiological building, but which has never yet been erected.

Very methodical and very tidy, he was an extremely painstaking and skilful dissector, an expert in an art which seems rapidly to be disappearing.

Langley had a certain reserve about him, but he was always willing and anxious to help. He would gladly lend an instrument or a book to any researcher, but he liked to know the date on which he was to receive it back, and if there was a failure in returning it he, quite properly, resented it.

For many years Langley was Chairman of the Board of Biology and Geology, and he took endless pains in the conduct of the business of that Body, which is ever increasing in magnitude and complexity. For a time he served on the Council of the Senate, and it was at his suggestion that the Minutes of that Body were printed and circulated, a proposal which was carried in spite of some vigorous opposition on the part of the more old-fashioned Dons. He lived to see the School over which he presided for the last twenty-two years increase and flourish. Under him the new buildings of Physiology were erected, and he spared himself no pains in superintending the plans and devising the fittings. His death after a very short illness was a severe blow to the many friends he had, not only in his College and throughout the University but to the scientific world at large.

Physiology, Pathology, and Epidemiology

At the meeting of the British Medical Association at Bath, in 1925, Dr. J. C. G. Ledingham, F.R.S., Professor of Bacteriology, London University, read a defence of pathology against recent criticisms of its achievements contained in the last Annual Report of the Medical Research Council, which seems to consist mainly of physiologists who naturally vaunt the merits of their own branch of science. Physiology and pathology at present divide most of the well-paid professorships in this country and receive most of the academical honours; and one can, therefore, watch their emulation without distress. Bacteriology, which is a large part of pathology, was created chiefly by the French and Germans in the latter part of last century, and seems now to be approaching something like exhaustion. It has not yet discovered with certainty even the causes of the principal zymotic diseases (*e.g.* the cause of smallpox, which is contained in a speck of vaccine), much less methods for their prevention and cure; and the whole population of Britain still goes through the winter sneezing with "colds," which are said to be produced by some scores of "germs," whose investigations seem to be more effectual than those of our doctors. As regards physiology, Dr. Ledingham remarks, " the main achievement claimed for physiology in these [last] five years is insulin, which, though it came from Canada, is regarded as the practical outcome of continuous research on diabetes, stretching back forty years." Frankly, even this success appears to have been made by a " mere doctor " in Canada (SCIENCE PROGRESS, April 1924), long after the gods of the physiological Olympus had commenced working at the subject but had given it up before reaching practical results—a common story. These same savants, however, still continue to blow great trumpets of triumph over *their* victory. We confess that we incline to the pathologists ; but the fact is, that the supreme triumphs of medicine during the present century have been due not to these, but to quite another set of men, also " mere doctors," who have shown that many of the great diseases of men and animals in the fairest regions of the earth are carried by " insects." These discoveries are not temporary and incomplete advances, each leading laboriously to the next, but definitive conquests of nature which will serve mankind as long as civilisation may endure. Yet the men who made them (chiefly British) are scarcely known to the Bœotian nation to which they belong, which gives them no gratitude for their work and which scarcely has the sense to utilise their discoveries for its own advantage.

Information-Bureaux Conference

THE idea of providing an opportunity for intercourse between those engaged in assembling and distributing information in the fields of science, industry, and public affairs, has met with success under the auspices of the Association of Special Libraries and Information Bureaux. Sir Arthur Steel-Maitland, Bt., Minister of Labour, opened a conference at Balliol College, Oxford, which lasted from September 25 to 28, and was attended by over 200 delegates of organisations ranging from the scientific societies and large libraries, to research institutes, and smaller associations of experts. The attendance included M. Otlet of the Institut International de Bibliographie, Brussels, and other visitors from Germany, Holland, and the United States, and the international aspect of the subject was further emphasised by a valuable address from Prof. Gilbert Murray, on the work of the Committee of Intellectual Co-operation of the League of Nations.

Dr. Chalmers Mitchell, F.R.S., spoke of the " World List of Scientific Periodicals," which has just been published with the help of the British Museum authorities, and which discloses the existence of some 25,000 separate journals, and for the first time gives a picture of a situation which is truly staggering. Organisation, co-operation, and the initiation of methods of exchange are obviously desirable to keep the community in touch with world sources of information of such gigantic dimensions. The problems of translation and collective abstracting were dealt with in papers by several of the leading authorities in the engineering and chemical sciences.

An attempt was made to give the conference some insight into the library methods of the daily and technical press, as it is obvious that those who are engaged in writing matter for more private distribution and service should find interest in the methods employed in the field of journalism. Of outstanding merit was a series of papers read by leading representatives of the library service departments of the three main political groups. The illustrations given of their organisation show that a high standard of intelligence service is aimed at, going far beyond any narrow party need of the moment. The information sections of such Government departments as the Board of Education, Ministry of Health, and Imperial Institute, were described, and certainly widened the knowledge of most of those present as to sources available in this direction. Mention was made of the encouragement given by Sir A. Steel-Maitland, when in charge of the Department of Overseas Trade, to improving the availability of commercial intelligence.

Sir Horace Plunkett described the Co-operative Reference Library, which it is hoped to transfer from Dublin to London, and which should prove of value in the attempt to develop our agricultural life.

Methods of filing and classifying library matter and correspondence were dealt with by Mr. R. Borlase Matthews, Mr. L. S. Jast (Chief Librarian of the Manchester Public Libraries), and others.

The field of general library administration is fully covered by the chartered "Library Association," but the friendly relations between this older body and the present gathering were demonstrated, and an attempt is to be made to explore the possibility of closer relations. This brief review cannot do justice to the public discourses, which numbered over thirty, nor do more than mention the even greater wealth of opportunity afforded by the intercourse of such a large number of specialists engaged in diverse callings. The most important future work of A.S.L.I.B. lies in the production of a Directory of Special Libraries and Information Bureaux containing brief annotated particulars of their scope and objects.

Particulars of the Association's work can be obtained from the Organising Secretary, Mr. G. W. Keeling, 38 Bloomsbury Square, London, W.C.1.

Notes and News

The President and Council of the Royal Society have, with the approval of H.M. the King, awarded a Royal Medal to Prof. W. H. Perkin, for his work on the constitution of the alkaloids ; and to Prof. A. C. Seward for his researches on the palæobotany of Gondwanaland. The following awards have been made by the President and Council of the Society :— The Copley Medal to Prof. A. Einstein, for his work in connection with the relativity theory and the theory of quanta ; the Davy Medal to Sir James Irvine, for his work on the constitution of the sugars ; the Sylvester Medal to Prof. A. N. Whitehead, for his researches on the foundations of mathematics ; the Hughes Medal to Mr. F. E. Smith, for his work in electricity.

Sir Ernest Rutherford has been elected to succeed Sir Charles Sherrington as President of the Royal Society.

The Nobel Prize for Physics for the year 1925 has been awarded to Prof. Siegbahn of Upsala.

The Chevreul medal of the French Society of Chemical Industry has been awarded to Prof. Henry E. Armstrong. Sir Robert Hadfield has been elected an honorary member of the Society.

Sir Alfred Ewing has been elected President of the Royal Society of Edinburgh, and Dr. F. W. Aston President of the Röntgen Society, both for the session 1925–6.

Dr. George Christopher Clayton, C.B.E., M.P., and Prof. Henry Cort Harold Carpenter, F.R.S., have been appointed by Order of Council to be members of the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research.

A Telford gold medal of the Institution of Civil Engineers has been given to Dr. Andrew Robertson of Bristol, and another, together with the Indian Premium, to Mr. S. A. S. Bunting of Bombay.

The Salter's Institute of Industrial Chemistry has awarded Fellowships for the year 1925-6 to Dr. R. Campbell, Armstrong College, Newcastle-on-Tyne, and University of Oxford, and to Mr. R. O. Gibson, University College, London. The Institute has also renewed four other Fellowships and has given seventy grants-in-aid to young chemists employed in works near London to assist them to continue their studies.

We have noted with great regret the names of the following workers in science in the obituary lists published during the past quarters : Dr. Friedrich Auerbach, chemist ; Prof. E. H. Barton, physicist ; Prof. O. Brefeld, mycologist ; Mr. F. J.

Brodie, meteorologist; Mr. J. Y. Buchanan, F.R.S., of *Challenger* Expedition fame; Dr. J. M. Clarke, American palæontologist; Mr. W. E. Cutler, field palæontologist; Sir Francis Darwin, botanist; Mr. J. S. Gamble, F.R.S., lately Conservator of Forests, India; Prof. Andrew Gray, physicist; Prof. H. H. Hildebrandsson of Upsala, meteorologist; Prof. F. R. Japp, chemist; Prof. F. Klein, For. Mem. R.S., mathematician; Prof. H. Maxwell-Lefroy, entomologist; Prof. O. Lummer, physicist; Capt. H. Riall Sankey, engineer; Dr. G. A. Schweinfurth, geographer and ethnologist; Sir W. Shlich, formerly Inspector-General of Forests for India; Dr. C. F. Sonntag, prosector to the Zoological Society, London; Prof. Charles Vélain, geographer.

At a meeting of the General Committee of the British Association held at Southampton on August 28, it was decided to accept an invitation to hold the meeting in 1927 at Leeds.

On Monday, August 31 last, Sir Ronald Ross opened the new British Mosquito-Control Institute which has been founded and equipped by Mr. J. F. Marshall in his own grounds at Hayling Island. The Institute will serve as a centre for mosquito study in this country, and owes its inception to the vast number of salt-water mosquitoes which used to infest the island. Happily this plague has now almost disappeared as a result of preventive work, which consisted mainly in the drainage of the inter-tidal areas round the island.

The fifth annual report of the Forestry Commissioners for the year ending September 30, 1924, states that in the period 1919–24, 39,469 acres have been planted by the Commission, which has, in addition, aided the preparation or planting of another 42,082 acres. On April 1, 1924, the Crown Woods of a total area of 120,648 acres were handed over to the care of the Commissioners, and they have also acquired an additional 141,470 acres of plantable land, the largest area, extending to about 20,000 acres, being near Thetford in Norfolk. Operations on this scale demand extensive nurseries to maintain the supply of young trees; no less than twenty-two million were required for the 10,000 acres planted in 1924.

Amundsen is planning another polar flight for the summer of 1926, and has purchased a semi-rigid airship of 670,000 cubic feet capacity for that purpose from the Italian Government. The airship, which has already several successful long-distance flights to its credit, is equipped with three engines giving a total of 750 horse-power, sufficient to give a cruising speed of about forty-five miles per hour. Its cruising radius is 3,725 miles, which, given good conditions, should be ample for the cross-polar voyage of 2,235 miles. It is intended that the airship shall be overhauled at Pulham early in 1926, after which it will travel to its starting-point, King's Bay, Spitzbergen, where a mooring mast is in course of erection. A crew of sixteen will be carried, including Signor Nobile, the constructor of the ship, who will act as navigating officer.

Prof. Miethe has made further experiments on the transmutation of mercury into gold by the electric discharge; he has obtained sufficient material in this way to enable Dr. Hönigschmidt to determine its atomic weight. This determination has given precisely the same result as is obtained with the ordinary metal, *i.e.* 197·26. Prof. Miethe has effected the transformation in a mercury-vapour lamp working at atmospheric pressure, and also by a discharge between two mercury electrodes embedded in paraffin wax. Meanwhile, Dr. Aston, working with an improved mass spectrograph, has obtained some preliminary data regarding the isotopes of mercury. He finds that the mass numbers of the principal isotopes are 198, 199, 200, 201, 202, 204, their relative intensities indicating an atomic weight in agreement with that obtained by chemical methods (200·6). These measurements make the nature of the mercury-gold transformation somewhat obscure since, when combined with Dr. Hönigschmidt's determination of the atomic weight, they show that the process cannot be one of a simple addition of an electron to the mercury nucleus. It is rather remarkable that the transmutation process should produce the isotopes in precisely the same proportion as they occur in ordinary gold, and the results obtained must be accepted only with reserve.

Dr. W. W. Coblentz has given an account in *Nature* (September 19 and 26, 1925) of a number of recent observations of stellar and planetary temperatures. Various parts of the infra-red spectrum of these bodies are isolated by suitable screens and the energy measured by thermocouples. In this way the distribution of energy in the spectrum can be determined, and hence, assuming black body conditions, the temperature of the source. From data obtained by Coblentz at the Lowell Observatory, Menzel has calculated the following temperatures: moon, 125° C.; Venus, 60° C.; Mars, −30° C.; Jupiter, −135° C.; Saturn, −150° C.; and Uranus lower than 185° C. These are apparently the mean temperatures over the whole of the planetary discs, and all observations indicate that the equatorial temperature of Mars, at perihelion, is considerably above 0° C., and probably between 15° C. and 20° C. In certain of these cases the temperature is greater than could be maintained by solar radiation alone, thus indicating that the interiors of the planets concerned are still relatively hot. Thus, for Mars, about 30 per cent. of the radiation would appear to be of planetary origin; for the moon no less than 80 per cent.

would appear to arise from interior heat sources and for Saturn, the temperature is somewhat greater than would be given by solar radiation. Observations on the stars show that their effective temperatures vary from 2,500°-3,500° K. for the red stars up to 14,000° K., or greater for the blue ones. It should be noted, however, that such figures give no indication of the temperatures existing in the interior of the stars.

It would appear that the long sought cause of the sensitivity of photographic plates has at last been discovered by Dr. Sheppard, who left London some years ago in order to work in the research department of the Kodak Co., Rochester, New York. Preliminary work by many investigators and notably by Dr. Toy of the British Photographic Research Association, had shown that, in all probability, there exists in the grains of the silver halide in the photographic emulsion minute nuclei of some foreign substance whose condition is changed by light in such a way as to enable them to become centres of development. Dr. Sheppard has now shown that these nuclei are specks of silver sulphide formed from the allyl isothiocyanate or allyl mustard-oil which is present in minute quantities in the materials used in the manufacture of the emulsion and which reacts with the silver halide grains to form the sulphide during the manufacturing processes. Further details and references relating to this work will be found in *Nature* (August 22).

Technical Paper No. 12 of the Fuel Research Board (H.M. Stationery Office, 1*s.* net.) deals with temperature conditions requisite for comfort in rooms. These conditions have been investigated by Mrs. Margaret Fishenden and Mr. R. E. Willgrass, whose experiments show that the most satisfactory temperature depends a good deal on the surrounding conditions. With no source of radiation 65° F. for air *and walls* was found to be most comfortable, but warmer walls (*e.g.* 67° F.) required a lower air temperature (61° F.) and *vice versa*. With air heating the requisite temperature depends on the draught being 69° F. for a wind blowing at 2 feet per second and 76·5° F. for a velocity of 8 feet per second. It was observed, however, that velocities in excess of 4 feet per second formed a distraction from mental work. No conditions of air heating in a sunless room were found to be really satisfactory for sedentary workers, radiation heating being far superior. In this case 55° F. was found to be the best air temperature with radiation at the rate of 75 B. Th. U. per square foot per hour. With an air temperature below 45° F. it was observed that a fire always produces the sensation of excessive heat on the side of the body exposed to it and of chilliness on the other side. Thus in climates in which the temperature remains very low for long periods open fires must be supplemented by air heating. The paper also discusses the relative costs of the different methods of heating, but questions of convenience and of costs other than that of fuel make this a very difficult question. Even the final conclusion that, in all cases, cost will depend on the heat insulation of the room (*e.g.* presence of double walls and windows), while impeccable from the view-point of thermal efficiency, becomes less certain when the reference is extended to include such questions as the effect of fresh air on human efficiency and doctors' fees.

A Concise Guide to Map Projections, by C. V. Gordon, B.A., and Frederic Evans, B.A. (Heffer, Cambridge, price 1*s.* 6*d.* net.) contains a useful summary of the various graticules used in the projection of the curved surface of the earth on to a plane map. The information given is classified under the headings: Appearance of Graticule, Name, Construction, Characteristics, Usage. No explanations are added, as the book is intended to be read with one of the standard works on maps.

Among the recent publications of the Bureau of Standards, Washington, is a critical review of the published data concerning the *Relation between the Heating Value of Gas and its Usefulness to the Consumer*, by E. R. Weaver (Technologic Paper No. 290). After a most exhaustive discussion extending over 100 pages of print it is concluded that the usefulness to a consumer of a given volume of gas is directly proportional to its heating value, or, in other words, the volume of gas consumed by a community under reasonably constant conditions is inversely proportional to the heating value. The investigation thus provides a complete and independent justification for the introduction of the therm in this country as the basis for payment. It also carries the corollary that the best heating value for the gas (*i.e.* therms per c. ft.) is that which the company can deliver at the lowest cost per therm, with the important proviso that it should be the duty of the company to adjust the gas appliances used by its consumers so that the gas supplied may be burnt to best advantage.

Among other papers issued by the Bureau were the following: *Spark Photography and its Applications to some Problems in Ballistics*, by Philip P. Quayle (Scientific Paper No. 508), containing an account of a comparatively simple method of photography and a large number of interesting photographs of the discharge of a revolver, etc. *A Flow Calorimeter for the Specific Heats of Gases* (Scientific Paper 503), giving a full account of an apparatus designed to measure the specific heat of ammonia vapour at pressures below 100 atmospheres and temperatures below 150° C., but suitable for other gases and vapours within this range. *Theory and Interpretation of Experiments on the Transmission of Sound Through Partition Walls*, by Edgar Buckingham (Scientific Paper No. 506) dealing with the theory underlying a method for measuring the acoustic transmittance of panels by means of observations in two closed rooms which are in acoustic communication only through the panel which is set up as a part of the partition wall between the rooms.

The August–September number of the American journal *Popular Astronomy* (published by the Goodsell Observatory of Carleton College, Minnesota) contains a good account of the new Zeiss Planetarium, first constructed at the request of the Deutsche Museum, Munich. This apparatus is an orrery on a large scale, since the apparent motions of the planets and stars are projected optically on a vast dome which forms the roof of a building able to accommodate 700 people. The diameter of the dome already constructed is 83 feet, but apparently arrangements are being made to increase this to 130 feet in future construction (and, be it noted, no less than six German municipalities have been able to afford to order one). The optical devices permit of the projection on to the dome of the sun, moon, planets, and the 4,500 fixed stars in the first six magnitudes, and by suitable gearing an astral day can be reduced to 4½ minutes, 2 minutes, or 50 seconds. The motion of the solar system can be still further quickened, so that a year can be traversed in 4½ minutes, 50 seconds, or 7 seconds.

A note entitled, *The Cleaning of an Object Glass*, by Herbert A. Howe confirms an impression that all chamois leather contains traces of grease, and is, in consequence, quite unsuited for cleaning glass ; soft old linen should be used instead.

The first number of Vol. 4 of the *Empire Forestry Journal* contains a long and important article on sand dune reclamation in Palestine, where the forester is confronted with a problem complicated both by climatic conditions and cost. There are also articles on forestry in India, Burma, Honduras, Columbia, Canada, and Sarawak, so that it would be hard to be interested in any branch of forestry and yet not find several articles of special interest in the journal. The number also contains a very complete digest of recent publications emanating from Africa, in addition to the usual reviews. A comprehensive list of forest officers of the British Empire is supplied separately as an appendix.

In *Nature*, October 24, 1925, S. Hirst announces the identification of the adult form of the so-called Harvest Bug, a larval mite which burrows under the skin of the legs (chiefly) in the autumn in many rural districts. He proposes the generic name *Trombicula* for this annoying little creature, of which the specific name is *autumnalis* Shaw. The adults were reared from chickens heavily infected with the larval mites and sent by Prof. F. V. Theobald and Mr. C. W. Goode of Wye. As many persons have experienced, the irritation caused by the burrowing larvæ may remain for months and even for years. Many similar parasites infest tropical jungles.

The London County Council (P. S. King & Son, London) issues an interesting little Handbook, illustrating travel and transport by land and water, as shown in the Horniman Museum at Forest Hill (1925).

A Conference of the Medical Committee of the British Empire Leprosy Relief Association was held at 24 Cavendish Square in October last. Sir Leonard Rogers, who appears to be the principal originator of the scheme, gave some interesting facts about new methods of treatment (*Times*, October 24). *Science*, October 9, 1925, supplement, p. x, refers to the successful use of radium in leprosy at the Leper Receiving Hospital at Honolulu. Of course, new " cures " cannot be accepted without wide and long trial.

The Times gives an amusing extract from its edition of a hundred years ago (October 21, 1825), describing the speech of Olinthus Gregory, a mathematician and journalist, to the Mechanics of Deptford. After glorying in the work of Arkwright, Ferguson, Herschel, Watt, Smeaton, Brindley, Nicholson, and Ramidge, the enthusiastic lecturer concluded by describing Englishmen as being " the most free, the most intelligent, the most inquisitive, the most virtuous people on the face of the earth." Many of these names are now forgotten, and we no longer admire such persons. Our " big men " of to-day are politicians, comic actors, tradesmen, and game-players—and our greatness is behind us. " To great men there is nothing small ; To small men nothing great."

Vol. II, No. 1 of *The Annals of the Pickett-Thomson Research Laboratory*, St. Paul's Hospital, W.C.2, contains a series of four laborious papers by Dr. David Thomson on measles, on new species of bacilli, and on chromogenic bacteria, finely written, printed, and illustrated. The difficulties of bacteriology seem to be increasing rather than diminishing with work done : as each door is opened new vistas appear, and the labour seems to be endless.

On October 10, 1925, Prof. Harold Maxwell-Lefroy, of the Imperial College of Science and Technology at South Kensington, was found unconscious in his laboratory, presumably from the effect of some gaseous insecticide with which he had been experimenting ; and he died four days later at St. George's Hospital. He was a capable student and teacher of economic entomology and had been Imperial Entomologist to the Government of India; but, as his death proved and his work often suggested, his enthusiasm sometimes outran his caution. Valuable lives like his need not and should not be risked in such a manner. He was only forty-eight years old at his death.

If there is any circumstance which reflects on the intelligence of the people in this country and America, it is the frequency with which some of their newspapers continue to publish the most ridiculous antivivisection propaganda. It would be interesting to inquire how many thousands or millions of cattle, sheep, hogs, rabbits, hares, fowls, ducks, snipe, quails, fish, lobsters, and so on, are slaughtered, often under very unpleasant conditions, simply to fill stomachs which would probably be much better fed on vegetarian diet—or merely for sport. Yet the owners of these organs and these sportsmen dare to slander and revile the very few men of science who are allowed to undertake occasional experiments on animals for the sake of the very boobies who abuse them. Thus, owing to the insufficiency of experiments on animals we are now being forced to massacre innumerable herds of beautiful cattle in consequence of the foot-and-mouth disease. The last possible folly we have seen is contained in a letter in which doctors are accused of killing poor innocent mosquitoes under the false supposition that they carry yellow fever and malaria! The fact is, that a very considerable proportion of people who are apparently quite sane in the usual relations of life are simply "cracked" on particular points. It is impossible to discuss such points with such people; and that is why so few men of sense ever attempt to answer the "press-campaigns" referred to. They have to do with what may be called monomorosis; and monomorons, from dipsomaniacs to cranks and criminals, abound everywhere and cannot be argued with.

One always wonders why it is that on the great annual commemoration of Armistice Day on November 11 the men of science, inventors, organisers, medical men, and others who took the leading part in winning the victory or saved thousands of lives during the long struggle should not be associated with the Royal Family at the ceremony. Why should such association be now reserved chiefly for our eternal politicians (so adored by our dull masses), although it was largely their stupidity which was responsible for the whole tragedy. One wonders whether the shade of Lord Roberts is present on these occasions.

Just when people thought that the foot-and-mouth disease of cattle was being conquered in this country, there came a great recrudescence of it, and 150 outbreaks occurred in 16 different counties in October and November last. The scientific management or mismanagement of the outbreak appears to have been in the hands of the same committee for years. Expert committees seem in this country to be often selected on the lines of comic opera ; and we confess we were glad when the President of the Royal Society, who is at least a great physiologist, was added to the board. Experts who have never " experted " are very common in this country, but poor Mr. John Bull must be beginning to scratch his thick head over the enormous bill which he is now paying in consequence of this disease—without much result.

There has been much discussion in the press regarding certain recent war-memorials and commemoration tablets. One writer records the entire list of these placed along the Victoria Embankment from Westminster Bridge to Blackfriars Bridge. They are twenty-five in number, and the only man of science among them is J. S. Mill. One wonders why he was included.

How slowly the mass of men advance in virtue or intelligence was shown by a report of a Bulgarian Commission, published in English papers on October 31, regarding the mischief done by the Greeks in the Bulgarian territory occupied by them for a few days previous to that date. They did little damage to buildings, but it is alleged that all the cattle and horses were taken away or killed ; all the poultry were killed and left in heaps ; all household furniture was removed ; the whole harvest of tobacco, rice, and wheat was removed or scattered ; and portraits of King Boris were mutilated, the eyes being cut out. We may remember that blinding was a favourite punishment in the worst days of Byzantine degeneration ; and, if the charges are true, the case must be one of moral reversion of a bad type.

Conquest for November 1925 informs us that the Americans are trying to work the iron, platinum, and nickel contained in a huge meteorite, alleged to weigh a million tons, which fell, probably some thousands of years ago, near Cañon Diabolo in Arizona. The total value of this buried visitor is estimated to be about ten million pounds.

CORRESPONDENCE

To the Editor of SCIENCE PROGRESS

ARE THE CONTINENTS ADRIFT?

From G. W. TYRRELL, F.G.S., A.R.C.Sc., Ph.D.

DEAR SIR,

In my Essay-Review on " Are the Continents Adrift ? " (SCIENCE PROGRESS, Oct. 1925, pp. 321–5), I made a remark (p. 324) describing a certain statement by Dr. Harold Jeffreys concerning Wegener's hypothesis of continental drift as a " physico-mathematical *ipse dixit.*" This has been objected to as a misrepresentation, and I therefore hasten to withdraw it. The remark was penned in a phase of reaction against that spirit of bright confidence in which mathematical methods are applied to geological problems by physicists and geologists alike, which has come to disaster so often in the past. But the phrase was altogether too strong as a description of Dr. Jeffreys's quite logical argument demolishing one of Wegener's inconsistencies, and I should be glad if you would accord me the opportunity of expressing my regret for having used it in this connection.

Yours faithfully,
G. W. TYRRELL.

UNIVERSITY OF GLASGOW.
November 13, 1925.

ESSAYS

THE ENCOURAGEMENT OF MEDICAL DISCOVERY—A SUMMARY (Sir Ronald Ross)

For many years past I have been advocating in lectures and the press some wiser methods for the public encouragement of medical discovery than those which are now employed. Such iteration is the only way to attract public attention towards any reform, however obviously needed. Suggestions which require serious thought are not easily advocated, and are generally met by the public with complete silence for years, or even for centuries, especially if the arguments are unanswerable. I flatter myself that mine belong to the latter class, because until recently they have received almost no public attention—though a few writers have opposed them. Quite recently, in Science Progress, vol. xix, pp. 296 and 465 (October 1924 and January 1925), I considered the case in full once more, giving and discussing almost all the arguments for or against my proposals. But we have been told that this mere reasoning is invalid ; that all doctors make discoveries ; that they ought to be honoured to ruin themselves over research ; that payment for their discoveries would be beneath their dignity ; that no one knows exactly who it is who has made any advance ; and other grotesque fancies. No reform is likely to be effected in my time ; but I may as well continue these efforts, and will do so now by giving a summary of my conclusions on the subject. These are as follows :

1. Actual medical discovery (as distinct from mere speculation or incomplete research) concerns or may concern the health and the life of the world's entire population, numbering from one to two thousand million persons ; it affects not only the present generation but succeeding ones ; and it is also indirectly connected with diseases of crops and of herds. The encouragement of it is therefore a matter of the first importance for all countries.

2. The history of science shows that nearly all the fundamental medical discoveries have been made by a few private persons working on their own initiative, in their own time, at their own expense, and often with the loss of more lucrative

professional opportunities. On the other hand, subsidised academical or institutional researches perform the important functions of confirming, extending, or utilising the fundamental advances made elsewhere.

3. At the present moment the British public have officially refused to pay any money at all for the encouragement of the fundamental discoveries, however important they may be, when already made by private persons, but are generously subscribing about one penny a head *per annum* (say £180,000 a year) for the subsidised medical researches. This is much less than the sums they are now giving, severally, for education, defence, politics, amusements, drink, medical treatment, and even for their churches. In other words, they rely for the fundamental discoveries upon the enthusiasm and sacrifices of private individuals, generally struggling doctors; and subscribe only a comparatively trivial sum for the (chiefly) secondary subsidised researches.

4. For example, recent discoveries, made by a very few persons, have proved that many of the most widespread or terrible diseases of men and animals are carried by insects and other intermediary hosts. These diseases are the curse of our tropical empire; and most of the discoveries have been achieved by British medical men at their own expense. But the Chancellor of the Exchequer, the President of the Privy Council,[1] and the Royal Commission on Awards to Inventors refused to allow any payment from the State for such work (*see* SCIENCE PROGRESS, pp. 113, 284, 635, 1920, and p. 286, 1921, and the *British Medical Journal*, March 6, 1920); and up to the present the professional men referred to have received no professional payment from their grateful and intelligent countrymen for these strictly professional investigations, which have conferred and will confer such great benefits upon the empire.

5. Not only, then, does the private medical investigator seldom reap any reward for his labours, even when they are brilliantly successful, but he is often actually penalised for them. He is apt to lose the emoluments of medical practice, not only from loss of time over his researches, but from a common feeling that research is incompatible with clinical efficiency (cases of Jenner and many others). The more successful his work, the greater jealousy does it create among some of his professional fellows; and the more original his work, the more surely will it be (*a*) virulently attacked by many for years; (*b*) then attributed by rivals to other people; and (*c*) often actually pirated, sometimes very successfully, by clever pretenders. Lastly, he is almost sure to be excluded (in this country) from lucrative appointments. In short, the successful private medical

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[1] The Rt. Honbles. D. Lloyd George, A. Chamberlain, and A. J. Balfour.

investigator is likely to receive much more punishment than reward for the benefits which he confers on the world, and, in some cases, will not even be remembered.

6. Such is "the natural history of discovery." A remedy ought to be found. In my opinion, a man who works professionally for the world at large is just as deserving of professional payment as one who works for a single patient. In both cases there seems to me to be an obligation of honour to give him professional payment—both in ethics and in equity. But whatever politicians may decide on this point (and they have rejected the argument hitherto), I am quite sure of one thing—that it is consummate folly on the part of the public, in its own interest, to refuse such payment. The general effect of this stupid refusal must be the same in science as it would be in other fields of work—to limit labour and to exclude the most capable men. The army of science requires the best men available: the state refuses to pay them even when they have done the most distinguished work; well then, the best men go elsewhere.

7. My proposal is that every nation should set apart a small proportion (say one-tenth) of the money which it spends upon medical research for rewards in the form of life-annuities to the men who have actually contributed important discoveries to the stock of human medical knowledge, whoever they may be. That is, I advocate a system of *payment for results* in addition to the system now in force, which consists only of *payment for expectations*. (Details as to the proposed mode of administration will be found in previous papers.)

It is necessary to conclude with the following remarks: National pecuniary support for research is a comparatively recent innovation, and the result is that the principles upon which the available money is distributed are not yet fully understood, either in this country or elsewhere. The actual distribution of the funds is principally or largely in the hands of people who have not themselves added much or anything to the stores of knowledge, and who often spend the money on subsidies, scholarships, and salaries for persons who may be enthusiastic enough but who may not possess any natural aptitude for obtaining valuable results. The fact is, however, that, as I have said, almost all the leading discoveries have been made by private persons, who, like the most distinguished poets, artists, and musicians, do possess these natural aptitudes. The true way to encourage discovery, as apart from futile effort, is to discover and to encourage the latter class of people; and they can be detected only by the results of their past labours.

Ergo, I advise my countrymen to put at least some of their money upon the men who have already proved their capacity by previous success. These men should be encouraged by every possible means to continue their work as they themselves best know how to do, instead of being condemned to idleness (as usually at present) by the indifference of the public. But this is not the whole of my argument. It is, I repeat, a point of honour for any individual to pay the physician who has saved his life: so, I think, it should be a point of honour for the public to pay the men of science who have saved, or will save, millions of lives by their researches. Since the time of Jenner, the British people, at least, have overlooked this little obligation. A " nation of shopkeepers " does not like paying for goods which have hitherto been supplied to it gratis by philanthropical enthusiasts. In the end, however, its ingratitude punishes chiefly itself; and the day will come when the refusal of the politicians referred to above will be looked upon as being probably the basest episode in British history.

We are glad to note that the Canadian Government has recently abandoned this attitude in connection with the discovery of insulin. Why do not our rich men sometimes follow the example of Alfred Nobel, instead of wasting their bequests, as they often do at present, on all sorts of doubtful or unproductive schemes? At present this country has no sense either of the importance of medical discovery or of gratitude towards those who have achieved it.

ESSAY-REVIEWS

THE PROGRESS OF LONDON GEOLOGY. By S. W. WOOLDRIDGE, M.Sc., F.G.S., King's College, London. Being a Review of: **Maps and Memoirs on the London District,** published by H.M. Geological Survey, 1915–1925.

THE structure and succession of the rocks round London is, at first sight, so simple that it might be supposed that the work of mapping them and elucidating their history was well-nigh complete. Actually this is far from being the case. The work on the old maps was well done, and the memoirs that accompany them are geological classics, but they showed very clearly how much more there was to be learned, and have served rather to stimulate research than to render it unnecessary.

The initial survey of the London District, conducted throughout on the 1-in. scale, was largely the work of the late William Whitaker. The information gathered by him and his colleagues was published in the form of large hand-coloured sheets. In 1872 *The Geology of the London Basin* was published as vol. iv of the *Geological Survey Memoirs.*[1] This was followed in 1889 by *The Geology of London,* in two volumes, which dealt with a slightly smaller area. These works were largely written by Whitaker. In them interpretation was subordinated to a detailed record of exposures and tracing of outcrops. They have been, and will continue to be, indispensable to the field geologist as exceedingly careful records of facts, and it is to be noted that they give detailed descriptions of sections which have long since disappeared and will never again be reopened. Nevertheless, they fail to give a connected picture of the subject, suitable for general reading. Such an account was supplied by Whitaker in his short *Guide to the Geology of London,* which, however, ran through several editions and was out of print by 1909. The opportunity was then taken of publishing four special colour-printed sheets covering the area immediately round London, and a small accompanying memoir was written by H. B. Woodward. This memoir was rather different in treatment from the earlier ones, for it gave an account of the large amount of research done by private workers, and accorded full discussion to theoretical points. It was lucid in style and admirable in arrangement, and filled a definite gap in the literature of the subject. The maps were largely based on the old 1-in. survey, but the results of the 6-in. survey of the Thames Valley drifts by Howe and Pocock were incorporated.

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[1] This superseded old sheet-memoirs on Sheets 7, 12, and 13 respectively.

This account of the earlier publications of the survey is a necessary prelude to a fair evaluation of their later work. In 1910 a re-survey, on the 6-in. scale, of parts of the London District was begun under the direction of Mr. Clement Reid. A start was made in the west of the basin, on both sides of the Thames, and the work was pushed gradually eastwards until 1915, when the exigencies of the war caused a temporary suspension. Mr. George Barrow had succeeded Mr. Reid as District Geologist in 1914, and during the war he did much to keep alive an interest in London geology, by publishing some of the results of his own work and that of his colleagues. In 1920 the survey was resumed under Mr. Henry Dewey, and has continued ever since. The results have been published from time to time in small colour-printed sheets and accompanying memoirs.

It is proposed here to review briefly the additions to knowledge resulting from this very considerable body of work, and it will be convenient to treat the several points in stratigraphical order. Only small areas of pre-Cenomanian rocks have been surveyed, and no striking new evidence has been obtained. A considerable advance has been made in the mapping of the Chalk, for since the publication of the older maps, the zonal subdivision of this formation has been considerably studied. Formerly regarded as a homogeneous and rather monotonous formation, it has been shown to be accurately and consistently divisible into palæontological units, the distribution of which, if shown on a map, throws much light on the physiography and tectonics of the Chalk tracts. It is not feasible, without the expenditure of labour disproportionate to the results achieved, to map the individual zones over large areas, and this has not been attempted on the new maps, but a welcome feature is the division of the Chalk into its three major groups. The Chalk Rock and its associated rocks at the base of the Upper Chalk have yielded their characteristic fauna at several places, and both on the Chiltern dip-slope and the Kent and Surrey Downs, the hard rock beds make a traceable feature, as also does the Melbourne Rock at the base of the Middle Chalk. If any justification is needed for mapping these smaller divisions, it is amply provided by a study of the Chiltern maps. The dissection of the dip-slope and escarpment is thereby brought out far more effectively than by the hachuring of the older maps.

Much information has been collected as to the distribution of the actual zones. This is particularly welcome in the Hertford area, where, owing to the relatively unfossiliferous nature of the beds and the masking by glacial drift, little has hitherto been known of the Chalk. In S.E. London the distribution of the zones beneath the Tertiary cover has indicated E.-W. folding of pre-Eocene date along lines coincident with, or related to, the similar folds of intra-Eocene or Miocene date. Before leaving the subject of the Chalk, we must also refer with appreciation to the accounts of its general palæontology appearing in the Dartford and London District Memoirs.

Our knowledge of the Eocene beds has increased in several directions as a result of the re-survey. The Lower London Tertiaries have been mapped from Epsom to Rochester on the southern outcrop, and from Marlow to Hertford on the north. A very full account is given of the south-eastern area, where the classification of the beds has been brought into line with that sketched by Professor Stamp. The most important new fact emerging from the work is the overlap of the Thanet Sands by the Woolwich Beds, and these in turn by the Blackheath Beds in the south of the Dartford Sheet. This not only allows the approximate reconstruction of the Thanetian coast-line, but it appears to indicate a continuous submergence of the northern flank of the Weald during early Eocene times. On the northern side of the basin various outliers of Reading Beds appearing on the older maps have been removed, since it appears that they are not *in situ*, but are large masses of Eocene material reconstructed by the passage of an ice-sheet from the west. Remarkable cases of glacial disturbance and overthrusting have been described at Cowcroft, near Chesham. A further interesting point has arisen concerning the lithological changes which take place in the Reading Beds, as they are traced towards the north-west. At Littleheath, near Berkhampstead, there occurs a large outlier of quartzose shingle and sand, which is regarded by Dr. Sherlock, the officer who mapped the ground, as pertaining to the Reading Beds. Quartz pebbles are not known in the Reading Beds nearer London, but occur in the outer fringe of the deposit along the Chilterns, as at Lane End. This is Sherlock's justification for grouping the Littleheath deposits with the Reading Beds, but they have been claimed by Mr. C. J. Gilbert as of Diestian (Lower Pliocene) age, and there is petrological evidence in support of this view. The problem still awaits solution.

The London Clay, long the Cinderella of the Eocene formations, has enjoyed a belated return of interest in recent years. This is largely due to the careful palæontological work of Mr. A. Wrigley, who has shown that it is possible to recognise distinct faunal divisions in the mass of the clay. It is not yet possible to map these divisions separately, and much careful collecting work remains to be done, but the Geological Survey has contributed materially to the solution of the problem by the publication of fossil lists. Those appearing in the older memoirs are surprisingly meagre, and the idea has become current that the London Clay is a poorly fossiliferous formation. This is far from being the case, and all exposures merit the closest scrutiny from the palæontologist.

In the older accounts, the existence of sandy passage beds between the London Clay and the overlying Bagshot Series, was recognised, but they were grouped with the London Clay. They cannot be separated from the latter stratigraphically, but they are lithologically distinct, and also support a somewhat different flora, as is seen at Shooter's Hill. The economic importance of separating these beds on the maps has long been clear. Cases are on record in which contractors have opened reservoirs in what purported to be London Clay, only to find themselves in laminated loams with numerous sandy seams, which offered every facility for the escape of the water. It is hence a matter for congratulation that these passage beds are shown by a separate colour on the new maps. They were first delimited by Dewey at Claygate in Surrey, and they are commonly known as the Claygate Beds. Since, however, we have no means of knowing that they everywhere occupy the same time-horizon, there is danger in thus assigning them a definite name. They occupy much of the high ground round London, especially in the Epping Forest district and throughout Essex, but thin out westwards. It is particularly interesting to note their occurrence on the heights of North Middlesex, for they rest here on a somewhat diminished thickness of London Clay, and the suggestion is thus conveyed that the clay is thinning fairly rapidly northward.

The Bagshot Series has come under the notice of the surveyors, both in the true Bagshot country of west Surrey and Berkshire and in Essex. The beds in the former locality were the subject of a long and indecisive controversy between Messrs. Monkton and Herries and Dr. Irving in past years, and while the work of the Survey cannot be said to have cleared up all the points at issue, it is satisfactory to note that they have found no difficulty in assigning definite and consistent limits to the three constituent formations: the Lower Bagshot Sands, the Bracklesham Beds, and the Upper Bagshot (or Barton) Sands. A rapid northward thinning of the Lower Bagshot Beds near Ascot seems to be well established by the new work, and goes far to prove the reality of the overlap of the Bracklesham Beds long claimed by Irving. The most important discovery, however, made in this tract is the occurrence of Lower Greensand chert in the Barton Pebble Bed. This fact has involved considerable alteration in our views of the rate of denudation of the Weald, and it opens up large questions as to the provenance of the Tertiary sediments in general.

In Essex large tracts of Lower Bagshot Beds have been surveyed and the old boundaries corrected in many places. Although the results are not yet published in full, a general account of the advances made is available in the annual *Summaries of Progress*. The chief error on the old maps was the recognition of a Bagshot Pebble Bed, which was shown capping most of the outliers, as if it were originally a wide-spread sheet. Messrs. Edmunds and Dines, who are largely responsible for the revision in Essex, have come to a conclusion, which is shared by most geologists who have worked on these beds, *viz.* that much of the so-called Bagshot Pebble Bed is a polygenetic gravel of later date. At the same time they have reopened the type section at Langtons and proved that a true Eocene pebble-bed does exist there, not at the top of the Bagshot Sands, but at their base. It would appear to be quite local in distribution.

The Geological Survey has always held itself aloof from the controversies concerning the several phases of post-Eocene history in the London Basin. This attitude is unquestionably the right one, since no semblance of finality has been reached in the discussion of these problems, and it would be unwise to select any one of the rival versions for official benediction. Nevertheless, the work of the Survey has afforded, in most cases, a sound basis for further work. It is largely owing to the energy and enthusiasm of Mr. George Barrow that the revision of the various drift deposits has been so successful. The cardinal virtue in drift mapping is consistency. It is relatively of little moment what name or age is assigned to a deposit, so long as that name is always used in the same sense. The new maps show a clear and logical classification of the drifts, based on their characters and disposition, rather than on opinions as to their age.

On the Chiltern dip-slope a new category of drift is recognised —the Pebbly Clay and Sand—which was formerly given the misleading name of Plateau Brick-earth, and was not clearly separated from the Clay-with-flints. Opinions may differ as to the origin and significance of this deposit, but it is certainly entitled to separate mapping. A clear distinction has been drawn between the high-level Pebble Gravel, which is a Pliocene or early Pleistocene shingle, and the later plateau gravels, with Bunter quartzites and other far-travelled material. This distinction, it is true, was made to some extent on the old 1-in. map, but there was little consistency in its application. In the special London sheets it was frankly ignored, the deposits being classed together as Plateau Gravels, and much harm has resulted from this. Whether or not one accepts Barrow's views on the early Pliocene age of the "Pebble Gravel," it cannot be doubted that he clarified the subject in a signal manner by his recognition of its wide extent, uniform elevation, and constancy of composition, and his insistence that it is immeasurably older than the so-called "plateau gravels." An outlying patch of the older gravels occurs at Shooter's Hill, and here good evidence has been obtained of its Diestian (Lower Pliocene) age. It is perhaps to be regretted that the officers concerned in mapping this area could not see their way clear to recognise this fact, and frankly class the deposit with the Lenham Beds. However, as stated above, their agnostic attitude has much to defend it, and the value of their mapping is not diminished by their unwillingness to commit themselves on a notoriously difficult question.

The work on the river drifts shows a great advance. At an early stage of the revision a classification was adopted for the several terraces of the Thames, which for the first time are shown in different colours. This classification has been applied with success to the deposits of the main tributary streams. The Geological Survey also collaborated with the British Museum in the investigation of the sequence of cultural stages at Swanscombe, an excellent account of this classic research appearing in the *Dartford Memoir*. Full details have, of course, been published elsewhere by the authors, Messrs. Dewey and Smith.

In concluding this review, reference must be made to the greatly improved scale of colours employed for the maps, in virtue of which they compare favourably with their predecessors as artistic productions. At the same time one may, perhaps, be permitted a word of criticism as to the policy pursued by the Survey in the mapping of soft deposits. In the geologically recent past the whole surface of the London countryside has been a mobile sludge, creeping slowly towards the lower ground. As a result, the geological boundaries rarely show a simple relation to the contours, and in many cases large masses have slipped bodily. It is doubtless of small moment to the agriculturist or engineer whether a bed is strictly *in situ* or not, and it is desirable that washes and slips should be shown on the map where they are thick and conspicuous. Nevertheless, great confusion must arise in the mind of the geological student when he sees London Clay mapped as resting directly on Thanet Sand. If he has no personal acquaintance with the district, he inevitably reads structural and stratigraphical interpretations into these purely superficial phenomena. Since the maps are widely used for educational as well as economic purposes, it is highly desirable that some distinctive sign should mark beds which are not *in situ*. Further, it is a regrettable fact that the new maps are not in all cases more accurate than the old. Several instances have come to the writer's notice of alterations which are not justified. This is not necessarily the fault of the Surveyor, whose task in mapping thin and unconsolidated deposits is far from an enviable one. Nevertheless, it should be remembered that the old maps have served as a basis of work for scores of geologists, and have in consequence been checked and re-checked many times in matters of detail. The note-books of private workers contain records of temporary sections which serve to confirm or correct the old boundaries. It is a pity that this large body of evidence is not more generally available to Officers of the Survey, whose task would thereby be greatly facilitated.

NOTE.—The publications referred to in the foregoing article are the *Memoirs of the Geological Survey* on the following districts, and the accompanying maps :

Windsor and Chertsey (1915)
South London (1921)
Beaconsfield (1922)
Aylesbury (1922)
Hertford (1924)
Dartford (1924)
North London (1925)

See also the *Summaries of Progress of the Geological Survey*, 1910–1924 ; and *The Geology of the London District*, 2nd ed., revised (1922).

THE PSYCHOLOGY OF INDIAN UNREST. By Col. W. G. KING, C.I.E., M.B., C.M., D.P.H. ; I.M.S. (ret.). Being a Review of: **The Heart of Âryavârta.** By The EARL OF RONALDSHAY, P.C., G.E.S.I. [Pp. xvii + 262.] (London: Constable & Co. Price 14*s*. net.)

THE frank offer to India of self-government within the Empire was made subject to a time-limit, estimated as sufficing to exhibit in practice both the loyalty and the ability of Indians of " light and leading " to engage in the supreme phase of administration. Astonishing results have followed. Instead of calmly and assiduously labouring to prove that the country welcomed the change, and that, as the days passed within the time-limit, peace and plenty materialised, the bulk of the period has been frittered away in verbose haggling by the intelligentzia thus entrusted with the task. The offer was, at least, magnanimous ; and its prompting was due to the belief that it would be received as confirming mutual trust in the honour of the country which made it and that which received it. Certain busybodies amongst the people of India, however, elected to say, and perhaps believed, that Great Britian would not fulfil its promise, and that the offer was a mere *placebo* in view of anarchical tendencies which from time to time had been exhibited. Moreover, they asked, were the offer genuine, why should their ambitions be subject to the nursery aphorism that " if a thing be good it is worth waiting for." Hence, strengthened by the futile assumption that the discretion requisite in politics and administration is necessarily intuitive, and hereditary in the case of descendants of an ancient civilisation, they desired to ignore the time-limit which would permit on their part accretion of experience and, on the part of Great Britain, the ascertaining that, in practice, the new-fledged administration did not forget that by the sword and pen, by sacrifice of British blood, by the sinking of millions of capital, India, from a condition of chaotic principalities, has been consolidated and afforded the opportunity of becoming a unit of significance in future world power. These busybodies have forgotten the rock-bottom fact that the interest thus dearly acquired will never be allowed by the British people to be regarded as a petty bauble—to be disposed of at the option of either an ephemeral orator or archaic sage. By facts not words alone can it be established that those who accept the offer also accept the axiom involved.

So far, what progress has been made ? Without forgetting that useful measures have been advocated by a loyal minority, to the average western mind the administrative necessities vaunted by Extremists (whose presence has largely neutralised this leaven of its value) have shown that the idol of self-government to which they would offer the bauble has feet of clay.

How is this unexpected result to be accounted for ? Has history repeated itself in that " someone has blunder'd," and if so, how ? That is the question Lord Ronaldshay has made it his task to answer, in his recently published work *The Heart of Âryavârta.*[1] In this he neither advocates nor disapproves of the offer of self-government, nor deals with the rather complex question of the origin of certain clauses in the documents concerned, but considers the problem as to why it has been received in a manner incomprehensible to the average Briton. This he has effected with the courtesy and impartiality that well befit a man who, in the rôle of Governor of the important Province of Bengal, for five years held the scales of might and justice under conditions not invariably pleasant. In a careful and interesting analysis of details of lore of the East little known to the British public, which he claims affords the web and woof of " thought-structure of the Hindu," he demonstrates how it has been possible for a people called upon to deal with materialistic facts to forget that, on this earthly plane, time happens to be a factor of no little importance and cannot be ignored by the mass intent on euthenics—whatever may be the predilections of individuals of a rhetorical minority in favour of the mirages and rainbows of abstract idealism.

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[1] *The Heart of Âryavârta,* by the Rt. Hon. Earl of Ronaldshay, P.C., G.C.S.I., G.C.I.E., etc. (Constable & Co., London, 1925.)

In following the author's arguments, it is well to remember that, according to the Census of 1921, the Indian Empire, including the independent States, has a population of nearly 319,000,000 ; that (without mention of dialects) 222 languages are current, 13 of which must be regarded as largely spoken ; that 161 males and 23 females per mille are returned as " literate "—a classification including not only those possessed of the higher forms of scholarship but also those merely able to read a letter from a friend and write a reply in any language —and that 16 males and 1·8 females per mille are literate in English. It is obvious that to attempt the tracing of modifications of thought-structure in so huge a population would entail the writing of many volumes. It so happens, however, that of the total population 89·8 per cent. may be classed as rural. Normally, these classes have neither knowledge nor interest in politics, although in common with the urban population (constituting 10·2 per cent of the total) they may be stirred to panic or vindictive action by ready and unquestioned acceptance of ridiculous and baseless rumours. In other words, Indians as a mass are emotional and find relief in spasmodic action (*karma*). The author, therefore, has proceeded to dissect the thought-structure of the intelligentzia, who by accident of possession of power, placed in their hands in trust by the British Government, are in the position at the present time to use or misuse this characteristic of the majority of their countrymen. No less than in the mass are emotional tendencies existent in certain sections of the intelligentzia ; but these find relief not in action but in debasing reason by building " castles in the air " and, in realms of unstable equilibrium and relativity, forget to summon to imagination the semblance of foundation, whilst entranced in the beauty of the superstructure of their fantastic creations.

But by no means does the author treat thought-structure of the Hindu thus summarily. The mosaic exhibiting his whole argument consists of well-adapted items. His method has been to suggest deductions, each of which he supports methodically by authentic details. He starts by quoting the assertion of Mr. Pal that the " fundamental conception of the Vedanta Philosophy is the world idea of the Hindu race," and with sympathy for much that this connotes traces its operation in thought-structure, till a point is reached where even the restrained occidental idealism of the author is touched by his visit to the school at Bholpur founded by Dr. Rabindranath Tagore. He relates that " led by a Pandit the pupils chanted Vedic Hymns in Sanskrit with striking effect . . . Here was a reproduction in miniature of the conditions amid which the civilisation of India had been born, the life close to Nature in the heart of the forests, which provided early Aryan settlers with all they required. One recognised in all one saw around one both a protest against the artificiality of modern life and an offering of homage to the ideals and positions of the past." In further illustration of Hindu thought-structure, he quotes the opinion of an educationalist of long experience in India, who summed up the mind of the Indian boy " as nearly the antithesis of the English boy," in that " he is highly imaginative and delighting in subtleties . . . a field of concrete facts only appealing to him as a stepping stone to the field of abstract thought." It would thus seem true in the East, as in the West, the child is father to the man.

These mere outlines may indicate the birth, though to the average western mind, in the light of concrete facts, they fail to justify the dreams of that section of the intelligentzia known as " Swarajists," who would fain rid India of the British bag and baggage, and would spurn western education, western art and industries. Thus free from alien influence, they hold they would be able to revert to conditions attending the civilisation and culture of India amidst peace and plenty,[1] as depicted by the late Mr. Das :

" We had corn in our granaries ; our tanks supplied us with fish ; and the eye was soothed and refreshed by the limpid blue of the sky and the green foliage of the trees. All day long [no strike for a forty-eight-hour week being feasible] the peasant toiled in the fields ; and at eve returning to his lamplit home, he sang the song of his heart." But these things were no more. " The granaries are empty of their golden wealth ; the kine are dry and give no milk ; and the fields once so green are dry and parched with thirst. [*Infelix ager!* Enormous extension of irrigation under British rule has been futile !] What remains is the dream of former happiness and the languor and misery of insistent pain." Two questions must arise in the average matter-of-fact western mind—is it possible Mr. Das really believed the statement he made. As to this the author's criticism is couched in the language of the experienced diplomat—he is of opinion there was exhibited " a fine disregard of historical accuracy." Of more importance is the second point which the diplomat leaves untouched, *viz.* did Mr. Das believe his statment would be credited. It may safely be assumed that he did, and that as a political agitator he deliberately calculated upon the emotional instincts of the people he addressed thrusting reason from its seat. The incident is typical of the position of the perverted thought-structure of Swarajist intelligentzia when brought in contact with the masses, whose interest they insist they represent. Mr. Das, probably in a state of *samadhi*, relegated to *maya* historical records of famines in India before the days when Company Bahadur was sufficiently established to inaugurate the grand task of care of the civil population, which, under the beneficent Queen Victoria and her successors, has been faithfully and toilfully fulfilled. As to the granaries remaining full after the revenue authorities of the good old time and the egotistical collecting agents had been remembered according to custom, and the *ryot* in the absence of coin had paid his labourers in grain, and had made a reserve for his family in case of famine, the prospect of repletion of the granary must have been the

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[1] Waves of invasion in India did not favour preservation of historical accounts of the economic conditions of the masses, even had that been regarded as of moment by the historian of the period, but the following rough data of conditions give a glimpse as they were in " the good old times " : FAMINES : According to Danvers and Walford there were severe famines in 503–443 B.C. and A.D. 1022, '52, '60. In and after the thirteenth century records are more available. Up to 1842, when relaxation of military watchfulness left increasing time for civil administration by the British, thirty-six famines are recorded. PUBLIC HEALTH : Vital statistics were not compiled by Indian authorities for the general population, but those for sepoys under the East India Company in 1821–33 show that cholera attacks were at the rate of 43 per mille per annum. In a recorded instance, the civil population when devasted by cholera threw their corpses in the fields to be devoured by *Kali*. The observer states that " the whole vicinage of the town was a

horrible charnel-house where dogs, pigs, jackals, and vultures held high revel." The earliest vital statistics for Calcutta show that 23 per cent. of total deaths (37–81 per mille per annum) were due to smallpox. Indians died at the rate of 51 per mille. PUBLIC SAFETY: Even the royal road under Aurangzeebe was infested with robbers and it is recorded " wayfarers cannot travel in safety." In the name of religion, cowardly murders were frequently committed by Thugs. The right of summary justice or injustice was frequently exercised by rulers. In certain areas, the *ryot* was expected to yield half the produce of his fields to rulers for revenue purposes. To surround a village with cavalry at night was one of the methods employed for collecting revenue. PUBLIC WORKS: The safety of great engineering works was ensured by human sacrifices, *e.g.* King Krishna of Vizianagar obtained the security of a dam by the sacrifice of sixty human beings. PRIVATE SAFETY: Wives were encouraged to be careful as to culinary arrangements by visualising the drastic remedy of *sutee*.

subject of "illusion." The analogy of the last ages of the Cymæan prophecy to the good old days of India doubtless appealed to Mr. Das, in the matter of "ideal" milk. Was it not in that dreamland age that "of themselves the goats shall carry home their udders distended with milk, nor shall the herds fear the mighty lions. Of itself thy cradle shall pour out for thee caressing flowers." A hypothetical "empty" granary of the present day would show that the *ryot*, *via* the railways (the resultant of British enterprise and largely of British capital), had the sense to barter the "golden wreath" of grain for more materialistic coin.

Whilst false history might serve its purpose in communal psychology, the extremists of the intelligentzia recognise that to secure action by one of their own classes, emotion must be stirred by appeal to more radical elements of Hindu thought-structure. By way of enforcing the bag-and-baggage conception, murders of both Europeans and Indians aiding them was their apposite reply to the offer of self-government. Those who were foolish enough to conceive that this procedure would be effective had little knowledge of the thought-structure of the *sahib-log*, who, while unfortunately often yielding to subtleties, are so little capable of imagination as at once to harden their hearts and be "at their best in tight corners." Such extremists were, however, wise enough not to run the chance of their own necks being in request. They adopted the method of selecting easily influenced educated young men, and, during months of cunning teaching, perverted the Vedas by exclusion of the context of vital clauses, and thus convinced them that murders were legitimate. A succinct account of this contemptible procedure is afforded by the author (pp. 125–127), who, as the late Governor of the Province concerned, speaks from inner knowledge. He ends his statement with the suggestion that this result "must be attributed in no small measure to the disappearance of all religious instruction from the schools, due to the assumption of a strict neutrality on the part of Government." There is truth in this plea; but what other course could be open to Government in its task of holding the scales of justice fairly amidst diverse religions? What form of religious instruction would connote the necessary morality and yet convey a message acceptable alike to the Christian, the Brahman, the Sudra, the Mohammedan, the Parsee, and the Untouchables? Moral aphorisms might be repeated after the Coué or indigenous parrot method of scholastic training and thus find a precarious settlement in subconsciousness, but even then would not touch the "foundation" within Mr. Pal's definition of Hindu thought-structure. Pandits may find ecstasy or *samadhi* in study of the few fragments of the true Vedas and the lengthy commentary thereon of Sankara ; even those outside the three thrice-born castes may hear (and not understand a word of) the melodious Sanskrit, but the *practical application of Hinduism to daily life* is not thus found, but in the laws of Manu. These enforce the superiority of the Aryan invaders over the indigenous races of India, whether it be in respect of what is known as common justice in the language of the West or social equality as thus summarised : " On account of his pre-eminence, on account of the superiority of his origin, on account of his observance of (particular) restrictive rules, and on account of his particular sanctification, the Brahmana is the Lord of (all) castes (*varna*)." Would religious teaching in schools find favour with Hindu intelligentzia did it not connote the requirement that whilst the three thrice-born castes may study the Vedas " among them the Brahmana (alone) shall teach it, not the other two ; that is an established rule " ? So long as these rulings of Manu are observed, so must the thought-structure of the indigenous races be limited in superstructure, whether the " foundation " be as described by Mr. Pal or not, and so long will 60,000,000 of human beings (not aliens but fellow-countrymen of patriotic Indians) be condemned to the extreme degradation of Untouchability. Did the indigenous races but awaken to this fact, they might well at the next communal election suggest that the bag-and-baggage doctrine be applicable not only to the British but to the Mohammedan and Aryan aliens.

The author approaches the hard facts of the case when he alludes to the disappointing results of efforts by western educationalists who have striven not to abolish eastern lore, but to weld with it those advances in science which were made in the centuries barren of learning in India between the zenith of Hinduism and the arrival of the British ; a period which, in all probability, would have been fruitful, had the protection of life and property in the successive waves of invasion of the country not been then the paramount object of men of light and leading. From the Universities there has been a stream for many years of about 2,000 graduates per annum. What has been their influence in securing the advance of India ? More is demonstrable about the progress of the graduates than of the aid their country has derived from them. When full-fledged the graduate is straightway married and is disposed of to the bride's family at a market value of about Rs. 6,000. He thereupon embarks upon a sea of domestic trouble and looks for financial relief. Employment is then sought—preferably under Government, and elsewhere only as a last resource. The employment market having been overcrowded for many years he may be content with a mere nominal wage, so long as he be allowed a footing; and, with the lapse of time, he finds himself devoid of initiative. In one direction only is there an outlet for imagination and love of subtleties—the offspring of his thought-structure—*viz.* the practice of law amongst a people who, sharing his instincts, will risk the last anna upon the outcome of a lawsuit. The successful *vakil* readily becomes the verbose orator. On the public platform he will preach of radical reforms, removal of the misery attending virgin widowhood, and will espouse the brotherhood of Indians, including the Untouchables; but off the platform he will unblushingly plead reasons why he cannot personally give practical effect to these sentiments within his own family circle.

For this absurdity of thrusting educated men on the country by the thousand without prospect of employment, many in the past have blamed the methods of the Educational Department, but the author claims for it that there was no choice; the demand for education of the nature given has been from the people. All who have dealt with public bodies in India will accept this statement. Funds for other desirable purposes were at all times difficult to secure, but the vote of Indian members of public bodies for expenditure on education could be safely counted on at all times. The acme was certainly reached under the late Mr. Gokhale, who secured an enormous increase in the pre-war budgets of the Government of India at a time when trade was vigorously representing the need of more wagons on the railway. Year by year expenditure on the Army had been decreased under pressure by Indian representatives, with the result that when the field was taken on the frontier and Mesopotamia in the Great War, antiquated and defective equipment was at disposal, with ulterior effect as to life and safety of their countrymen. It is, therefore, a curious aspect of communal psychology to find that a people who but a short time back literally clamoured for western education should now demand that it be put aside, in favour of archaic philosophy to be communicated in the main by the medium of the vernaculars.[1] Here repercussion is evident of a type showing emotion sufficient to conceal from reason concrete facts. Graduates are duly produced not in proportion to any ruling by the Government of India, but in accord with public demand. Had the sciences been looked to as affording careers for young men, undoubtedly necessary public funds would have been forthcoming for the purpose. But the possibilities of " Government employ " or practice of lucrative law, were the goal sought by Hindus of the higher castes carrying with them the traditions of clerical work of the nature demanded by Nawabs and Rajahs of olden days for collection—the *disbursement* was managed often by other than the scribes—of revenue. Caste prejudices for many years prevented medical and sanitary careers being desired, but with the lapse of time these are also in favour.

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[1] This may be justified by the hysterical sentiment accompanying the *sharka* and bag-and-baggage policy, but would be destructive of the Swarajist dream of welding the speakers of 222 languages into a nation. For this, a *lingua franca*, not evolved in the lapse of centuries but ready-made, is essential—the nearest approach to which is offered not by Bengali but by English or Hindustani. Difficulty in acquisition of English by Bengal University students mentioned by the author is a peculiarity not common to other parts of India, as shown by the higher standard of Matriculation Examination demanded elsewhere. (Educational Department Notification, Fort St. George, No. 169, December 1908.)

The result at the present day is that the unemployment of graduates is as acute a question in India as the unemployment of labour in Great Britain. Swarajism grafted upon the thought-structure of Hindus contaminated by western culture is liable to produce unhealthy plants. Why is such a suggestion necessary? Has the Educational Department done its duty when inculcating western learning? The Government of India had before it the reasonable premiss that British culture would lead to the appearance of patriotic Indians, whose aim in life would be the adaptation of western science, in its various departments, to the development of the natural resources of the country; that at intervals scientific inventions of utility, not only to India but to the world at large, might well be expected; that educated men would desire their women to be educated and freed from numerous disabilities; that patriotic Indians would have conferred upon the lower castes of their countrymen freedom from their degradation without incitement thereto by Government; and that the social customs tending to penury and (from a communal economic point of view) to unsound investments (for example, as represented by the *sowcar* and his agricultural client) would have been suitably modified. The author shows (p. 21) that economic development was foreshadowed in Sir Charles Wood's dispatch of 1854, which declared the intention to " teach the natives of India the marvellous results of the employment of labour and capital, rouse them to emulate us in the development of the vast resources of the country, and gradually but certainly confer upon them all the advantages which accompany the healthy increase of wealth and commerce." These results could have been obtained, and are still possible, without diminishing one iota the love of the educated man for the philosophy of his countrymen, as ably pleaded by Sir Asutosh Mukerji and quoted by the author (p. 245). But the stock reply to investing money in the development of the resources of the country is the " poverty of India." This is illusion (*maya*). Money is forthcoming for ultra-safe investments, *e.g.* in 1913 the Upper Sind Light Railways required a loan of Rs. 500,000. Subscriptions poured in beyond the day of closure till the capital offered exceeded Rs. 6,000,000. There is no lack of necessary funds, no lack of natural resources, which, in their development therewith, would secure a new India where both brain and muscle of all classes and castes would find ample employment and material advantages. In short, the " foundation " factor of failure to effect advances in the direction indicated in Sir Charles Wood's dispatch is not the incompatibility of industry and commerce with the spirit of Vedantism, but with the " thought-structure " of the holders of finance in India—the *sowcar* and his ilk. They have for centuries prospered on cruel interest wrung from the agriculturist and townsman alike—often the burden of debts incurred by the father being borne by the offspring. In commerce they are loath to take anything beyond a well-ascertained average risk ; their minds revolt from parting with money with little or no interest during the latent period ordinarily essential when factories and new trades are inaugurated. *The remedy is in the hands of the practical patriot* who would insist upon modifications of family interdependence and of puerile social customs, in advancing money for which the *sowcar* fattens. Sir Charles Wood's dispatch is dated 1854 ; beyond the Tata Company no really great industrial concern yet exists in India. Almost ten years later, Japan, which also has its system of Philosophy and its *samadhi* desires, awoke to the necessity for encouraging industry and commerce. The present day contrast in advancement in these respects of the two countries is obvious.

But it would be wrong to believe that amongst the Extremists of " light and leading " in India there is no man who sees that in the economic development of the country rests its present prosperity and future as a world unit, or that they are not rich in able politicians. Did not Mr. Gandhi visualise that the cooly with the hand spinning wheel (*charka*) could successfully compete with western machinery ? Did not the Swarajists propose to flout the money markets of the world by presenting an unbalanced Budget to the Government of India ? Have they not attempted to whittle away the martial defence possibilities of the country until the tenuous condition of thought-structure is exemplified ; and do they not desire abolition of protection within the British Empire, in the presence of evolutionary conditions in at least three countries of Asia, well knowing that the lapse of a generation will bring forth conditions (however imaginative and subtle alliances may have been hoped for) which must be met by materialistic agencies—a guide to which is not found in archaic philosophy.

INTELLIGENCE OF CHIMPANZEES. By Prof. J. Arthur Thomson. Being a Review of **The Mentality of Apes**, by Wolfgang Köhler. [Pp. viii + 342, with 9 plates and 19 figures.] (London: Kegan Paul, Trench, Trübner & Co. Price 16*s.* net.) And **Chimpanzee Intelligence and Its Vocal Expressions.** By Robert M. Yerkes and Blanche W. Learned. [Pp. 157.] (Baltimore: Williams and Wilkins; London: Baillière, Tindall & Cox, 1925. Price 17*s.* net.)

The importance of Prof. Köhler's work is twofold: (1) the observations were made on healthy animals, living together cheerfully, in a suitable place (Teneriffe); (2) the observer is an expert psychologist, familiar with the pitfalls in the study of animal behaviour, such as attaching importance to an isolated fascinating achievement. What he has done is to show that chimpanzees often solve problems in an intelligent way, appreciating the significance and relatedness of different links in a chain of acts, making perceptual inferences in reference to visible situations. Thus they would put one box on the top of another, even making four-storeyed erections, in order to reach a banana suspended from the roof. They learned to join two pieces of bamboo rod together in order to make a length sufficient to reach a prize outside their cage. One of them bit at the end of a piece of stick, reducing the end till it was of a size suitable for insertion into a bamboo rod that had to be lengthened. There are many such examples, well-documented and well criticised. It is true that chimpanzees must have the factors for the solution of the problem within their visual range, for they seem to have a very limited capacity of working with mental images; but they are far more intelligent than was suspected.

Prof. R. M. Yerkes, an expert in the study of animal behaviour, has made intimate and careful observations on two young chimpanzees. The details are of great interest, so much depends on the precautions taken to avoid fallacious inference; but we cannot do more than indicate some of the outstanding results.

It is plain that there are very marked individual differences, and that bodily health counts for much. The male, Chim, who was in vigorous health, showed himself sanguine, venturesome, trustful, friendly, and energetic. The female, Panzee, who was in poor health, showed herself distrustful, retiring, and lethargic. Chim's behaviour suggested in most cases unusual intelligence, but Panzee's suggested stupidity. This points to the importance of the health factor. Sometimes the difference in behaviour might have to do with sex. Thus the male habitually strove to evade the disciplinarian, while the female tried to get into his arms. One day Chim carefully plucked some blossoms and presented them to a lady attendant. He would dance in a lively way, keeping time to music, but

Panzee, though interested in music, never danced. Chim constructed nests, but though Panzee once or twice climbed the tree to take a look at one, she was not much interested, nor did she build herself.

There was abundant evidence of high sensory equipment, visual in particular. But again, it was the vigorous Chim who was most interested—even in the distant mountains! He also was much quicker to appreciate something of the significance of a new situation. It was also very striking to see Chim dealing with a juicy orange halved across the equator, for after a little experimentation he learned to extract the pulp without losing a drop of the juice. Panzee's technique in eating a half orange was crude and careless in comparison, and commonly resulted in the loss of more or less of the juice.

Of intelligent insight the best example, we think, is in connection with lifting one box on to another in order to secure a banana which was otherwise out of reach. The solution came within five minutes. Dr. Yerkes has no doubt that Chim worked with ideas and made inferences. "Most surprising and impressive in Chim's behaviour," he writes, "was the continuity of attention, high degree of concentration on his task, evident purposefulness of many, if not most, of his acts, his systematic survey of problematic situations, his rapid elimination of unsuccessful acts or methods, and his occasional pauses for reflection."

Mrs. Learned's contribution is a careful record in musical notation of all the sounds habitually uttered by the chimpanzees already mentioned. They fall into four groups, according as they were made while waiting for food, while eating, when in company with persons, or when two chimpanzees were together. Seventeen begin with gutturals, like *gho* in greeting friends; four begin with an aspirate, like *ho—oh* in alarm; five begin with nasals and labials, like *ngak* a food-word; five begin with vowels, like *ah—oh—ah* a half-scream of apprehension. There is a larger repertory of vocalisations than was suspected, and these might form the basis of a language if the chimpanzees began to imitate sounds persistently as parrots do. But there is almost no trace of this. So Mrs. Learned concludes: "Although the young chimpanzee uses significant sounds in considerable number and variety, it does not, in the ordinary and proper meaning of the term, speak."

These three investigations taken together mark a noteworthy advance in our understanding of the chimpanzee, and Prof. Köhler's work seems to us to be one of the most important contributions yet made to Comparative Psychology.

REVIEWS

MATHEMATICS

Summation of Series. Collected by L. B. W. Jolley, M.A. (Cantab.). [Pp. xi + 231, including many pages left blank for additions by the reader.] (London: Chapman & Hall, 1925. Price 13*s*. 6*d*. net.)

Those who desire to study natural problems accurately, and therefore quantitatively and mathematically, but who are not professed mathematicians, often find themselves signally defeated by the sudden apparition of series, the summation of which they cannot discover in their books, or cannot always even obtain from their more learned friends. This is often especially the case in biological or epidemiological work; and the textbooks are frequently either too general or not general enough. This book will therefore serve a very useful purpose. It contains twenty-eight chapters, each of which deals with a class of series, from arithmetical and geometrical progressions, powers of natural numbers, exponential and logarithmic series, trigonometrical summations,elliptic functions,and Fourier's series,to series involving Bernouilli's and Euler's numbers. The series itself is given on the left page, and its sum on the right page, without proofs or unnecessary explanations; but there is always a reference to previous and more general works in which proofs and details can be found. A feature of the book is the presence of numerous blank interleaved pages on which the reader may insert his own additions. There appear to be some misprints—as, for instance, in the series numbered 9, 32d, 59, 88c, noted only in the first eight chapters. The printing is clear and spacious.

In Science Progress for October 1915, January and April 1916, and October 1918, I described what I called an "operative" notation which enables us to denote series of many kinds besides simple summative series or continued products, and which, with some obvious extensions, would enable us to supersede the cumbersome symbols now in use for such processes as well as to study altogether new kinds of series. It is a pity that these proposals met with no consideration among mathematicians; they might have helped largely in the arrangement and scope of this excellent work.

R. Ross.

Four-Figure Mathematical Tables. By G. W. C. Kaye and T. H. Laby. [Pp. vi + 26.] (London: Longmans, Green & Co., 1925. Price 1*s*. net.)

A well-arranged little book which will be convenient for the less-exact calculations chiefly required in laboratory work. There are fourteen classes of tables, such as logarithms, natural trigonometrical ratios, logarithmic tables, powers, roots, and reciprocals; and it is a distinct advantage that each class, except the last, is confined to two opposite pages. The work has been prepared at the request of the Melbourne University Press.

PHYSICS

Handbuch der Radiologie. Band VI. "Die Theorien der Radiologie." Bearbeitet von M. v. LAUE, P. ZEEMAN, H. A. LORENTZ, A. SOMMERFELD und G. WENTZEL, GEORG JOOS, E. RIECKE, L. VEGARD, und P. DEBYE. [Mit 141 Figuren und Abbildungen im Text und auf Tafeln. Pp. xi + 807.] (Leipzig: Akademische Velagsgesellschaft, M.B.H., 1925. Price 40 gold marks.)

THIS volume marks the completion of the *Handbuch der Radiologie*, and gives a good account of the state of mathematical and experimental investigations of the properties of the electron and allied subjects up to the beginning of 1924. The names of the collaborators alone are sufficient guarantee of the excellence of the volume.

The first two sections are written by M. von Laue, and the first of these deals extensively with the motion of electrons and ions in fields of force, whilst the second gives a very complete account of the theoretical aspect of the passage of α- and β-rays through matter, in which the work of Henderson, Rosseland, and Wentzel receives due recognition. Prof. P. Zeeman contributes a most excellent description of the more recent experimental work on the magnetic resolution of spectra lines, supplemented by many interesting figures and tables to illustrate the rules which govern the Zeeman Effect, and the work of van Lohnizen, Sommerfeld, and Back is very clearly presented. This contribution is followed by a discussion of the theory of the Zeeman Effect by Prof. H. A. Lorentz, which is noteworthy for the clearness and conciseness with which are treated those cognate branches of the quantum theory such as Bohr's correspondence principle. This principle is elaborated in the section on the application of the quantum theory to atomic structure by A. Sommerfeld and G. Wentzel; this section is, of course, purely mathematical, and in it no extensive comparison of experimental and theoretical results is attempted. The experimental basis of the quantum theory is, however, by no means neglected, and the following article, by G. Joos, deals fully with the methods and results of the excitation of atoms by radiation, electron impact, and by charged and neutral atoms. Collisions of the second kind, first emphasised by Klein and Rosseland, receive adequate treatment. The results of some more recent experiments, such as those of H. D. Smyth and of Wood and Ellett, are considered in an addendum. A glance at the long list of references gives an indication of the scope of this article, and, incidentally, of the fairness with which the work of English and American workers has been incorporated in this volume.

Prof. Riecke's article of over 200 pages was written in 1913, but has been edited and revised by M. von Laue, who has succeeded, by means of footnotes and the addition of a few subsidiary chapters, in bringing the article up to date with a minimum of alteration of the original manuscript. Von Laue's additions are everywhere clearly marked, and the completed article thus forms a comprehensive survey of the theories of the emission of electricity by hot bodies, the conduction of heat and electricity, and of thermo-electric, galvano-magnetic, and thermo-magnetic effects. He has added an important subsidiary chapter on electrical conductivity at very low temperatures. Incidentally, von Laue also contributes a short description of the Compton Effect.

L. Vegard contributes a full account of Aurora phenomena and the hypothesis of cosmic radiation on which they are explained, together with a description of laboratory experiments which support this explanation, including an account of his researches on the spectrum emitted when solid nitrogen is bombarded by electrons.

The theory of the electric and magnetic properties of molecules is naturally most ably given by P. Debye, and the third chapter of his contribution, on the molecular theories of magnetisation, is particularly distinguished for its wide range and clearness. It forms a very complete guide to the large amount of experimental and theoretical work in a branch of physics which presents much difficulty to students, and in which, moreover, many physicists confidently expect to see the solution of a large number of problems of atomic structure.

This final volume of the *Handbuch der Radiologie* may fittingly be described as a great and lasting work, and will form an important book of reference both for mathematical and experimental physicists.

L. F. Bates.

A Treatise on Light. By R. A. Houstoun, M.A., Ph.D., D.Sc. [Fourth edition. Pp. xi + 486, with 334 diagrams and two coloured plates.] (London: Longmans, Green & Co., 1925. Price 12s. 6d. net.)

When Dr. Houstoun's book was first reviewed in Science Progress in 1916, the hope was expressed that this admirable treatise would speedily find its way into the hands of the students at our universities. Since four editions and one reprint have been called for within ten years, that hope has certainly been realised. The changes to record in this edition, as distinct from the third edition, are only slight; some few pages of the chapter on spectroscopy have been rewritten and minor improvements made elsewhere throughout the book. We again wish it every success.

L. F. B.

The Spectroscopy of X-Rays. By Manne Siegbahn. Translated, with the author's additions, by George A. Lindsay. [Pp. xii + 287.] (London: Oxford University Press, 1925. Price 20s. net.)

When the Braggs first demonstrated the now well-known structure of the common alkali halides, they may be said to have killed two birds with one stone—one, the difficulty of getting at the ultimate details of crystalline form; the other, the difficulty of the true nature of X-rays. The metaphor is a thoroughly bad one, for what actually happened was that one bird was played off against the other. Crystals gave away the undulatory nature of X-rays together with absolute values of wave-lengths, while X-rays in turn revealed the secrets of their betrayers and showed how they are the most orderly systems of particles that the heart could wish.—But that comes of two opponents being very much of the same size.

It is remarkable how simple was the solution of these two problems, so simple, indeed, that the consequent advances in atomic physics have been truly prodigious. The subject almost immediately commanded universal attention. It grew rapidly out of hand and specialisation became essential. The result was two subdivisions, each of paramount importance for physical research—crystal-analysis and X-ray spectroscopy. The crystal-analyst uses X-rays to determine crystal-structure; the X-ray spectroscopist uses crystals to analyse X-rays. That the conclusions in both branches are now, after only thirteen years, striking and far-reaching is apparent at once from the large series of works available. We have recently made acquaintance with some very able and exhaustive works on crystal-analysis, and a corresponding production was demanded of X-ray spectroscopy. We have it now in Prof. Siegbahn's *The Spectroscopy of X-Rays*.

This book, now issued by the Oxford University Press as an English translation of the German edition of 1923, is the work of an expert in his subject. Siegbahn's laboratory at Upsala has a world-wide reputation for painstaking and accurate research in the measurement of X-ray wave-lengths, and the first part of his book is very properly devoted to a description of the apparatus and technique which he has made his special study. The book, on the whole, is intended for the specialist, but this intention of the author is more particularly evident in his first chapters. There is a wealth of drawings and photographs of apparatus which one with no previous acquaintance with the subject might find difficult to unravel. Of course, there is the other extreme, where every single screw is labelled and described, but perhaps just a little bit more of explanation would not be out of place with some of the diagrams of this book. However, the author will readily be forgiven for his reluctance to convert his treatise into a physical catalogue, especially since a real knowledge of apparatus comes only from diligent use of the same. The general standard of excellence of the work is so high that we think it would be difficult to find any other fault with it—if the point mentioned can really be described as a fault.

The Spectroscopy of X-Rays should be in the hands of all whose work involves the use or a knowledge of X-rays. It is an indispensable handbook with a note of authority. Only one-third (some eighty pages) is spared for the discussion of apparatus and technique. The rest bears us pleasantly through a fascinating study of the results: emission spectra, absorption spectra, the systematic arrangement and theory of spectra, the continuous spectrum, and, finally, miscellaneous methods of arriving at the inner energy levels of the atoms. The author has gauged his treatment of all these branches to a nicety. He has endeavoured to introduce, and has succeeded in introducing, without making the book at all stodgy, all results and suggestions which appear to throw light on the problems of X-ray spectra. He has given just enough mathematical treatment to prevent the book becoming difficult to read, so that at the end one closes it with the thought: "How delightfully simple X-ray spectra are after all!" The author is keen, wherever possible, on letting one know just what are the latest developments of the subject; for instance, the important discovery of Lindh that "the X-ray absorption spectrum of an element varies greatly according to its chemical state in the compound investigated." Throughout, the argument is illustrated and borne out by numerous diagrams and tables. The tables, in particular, must be emphasised. There are no fewer than fifty-one in the text and six in the appendix. They and the bibliography will delight the heart of the spectroscopist, especially the last table of all, which gives the principal X-ray spectral lines of the elements arranged in order of their wave-lengths. Prof. Siegbahn uses his own nomenclature for these, for reasons which most people will grant to be sound.

The translator, Prof. Lindsay, of Michigan, and the Oxford University Press are to be congratulated on the production of a really pleasing English edition of an outstanding work.

W. T. ASTBURY.

Le Principe de Symétrie et ses Applications. Par F. M. JAEGER. Traduit de l'anglais par P. GÉRALD et J. CHEVRIER. [Pp. xv + 417.] (Paris: Gauthier-Villars et Cie, 1925. Price 55 frs.)

PROF. MOUREU, in his admirable introduction to this first French edition of *The Principle of Symmetry*, says: "Peu connu chez nous, le traité de M. Jaeger tient une place fort honorable, par contre, dans beaucoup de bibliotheques et de laboratoires étrangers. . . ." There is little need to say more than this here, for it is eminently true that Prof. Jaeger's masterpiece does hold an honourable place in English scientific libraries. It is far too well known among crystallographers and chemists alike to require any "rechauffé" treatment in this review. Chemists are usually rather nervous of tackling a treatise on crystallography, but they seem to have taken to Jaeger's book. The author is distinguished equally as a chemist and as a crystallographer, and he has succeeded in striking a note of harmony between two sisters who are struggling for comradeship and who must inevitably, sooner or later, join forces and work in permanent co-operation. It will be a happy day when all chemists receive a thorough grounding in the lessons of crystallography and all crystallographers are alive to the needs and problems of chemistry. It is no mean accomplishment on the part of Prof. Jaeger to have brought out so clearly that important point which, in the past, the chemist has been somewhat apt to lose behind the gigantic figure of the asymmetric carbon atom—that the true criterion for non-superposability is not merely the absence of a plane or of a centre of symmetry, but of all second-order symmetry elements.

The Principle of Symmetry belongs to that fascinating class of books which one never feels to be " studying," but just " reading." It treats of symmetry in general, of the animal, vegetable, and inanimate kingdoms, in a way that anyone who has considered the beauty of the Universe must find irresistible. It is the last part of the book that appeals particularly to chemists. Prof. Jaeger is in his element when talking of that noble harvest which has sprung from the seed of the immortal Pasteur.

W. T. ASTBURY.

Electricity and the Structure of Matter. By L. SOUTHERNS. [Pp. 128, with 33 figures.] The World's Manuals. (London: Oxford University Press, 1925. Price 2*s.* 6*d.* net.)

A PLEASANT little book, intended for the consumption of non-scientific readers who feel the need for a certain amount of enlightenment with regard to those terrible twin mysteries, electricity and the atom. A few such chatty little expositions of modern scientific ideas should go far to clear up the confusion so widely spread by prevailing journalistic nonsense. There are still too many people about who think that the essence of electrical science lies in the twiddling of knobs and the closing of switches. We were recently informed very seriously by a wireless " fan " that the " ohm " was a measure of sound ! If only to clarify this gentleman's notions, we would recommend to the author a revision of the following (p. 29) : " A simple relation existing between these quantities (current, electromotive force, and resistance) was discovered by G. S. Ohm (1787–1854), Professor at Munich, and stated in 1827 in the celebrated law which bears his name. The law states that the electromotive force which drives a current through a conductor of given resistance is equal to the current multiplied by the resistance."

It is gratifying to notice the homage paid by the author to the *pioneers* of electrical and atomic theory. All the credit nowadays goes to those whose business is the commercial aggrandisement of principles won by men whose names and struggles are comparatively unknown to the mass of the reading public. *Electricity and the Structure of Matter* endeavours to give honour where honour is due, and to emphasise these same principles rather than their technical and commercial aspects. In the theory of compound formation (p. 116), fairness demands the inclusion of the names of G. N. Lewis and W. Kossel.

Figs. 6 and 8 (on electrolysis, p. 20) appear to need interchanging. The general impression of the book is one of clearness and simplicity laid out to the best advantage by the usual fine workmanship of the Oxford Press.

W. T. ASTBURY.

Úvod do Chemie Radioaktivnich Làtek. (An Introduction to the Chemistry of Radio-active Substances.) By A. S. RUSSELL, M.A., D.Sc., translated into Czech by DR. A. ŠIMEK, Professor of Physical Chemistry at the Masaryk University, Brno. [Pp. x + 116.] (Brno: Nakladatel A. Piša, 1925. Price 20 Czech crowns.)

IT is perhaps remarkable that, although the radium mines of Jachymov (St. Joachimsthal) are situated in Czecho-Slovakia, the Czech language does not possess a treatise dealing with radio-activity, and Prof. Šimek is to be congratulated upon giving his countrymen this translation of Prof. Russell's *Introduction to the Chemistry of Radio-active Substances*, published by John Murray.

In the preface Prof. Šimek states his reasons for selecting this particular work for the benefit of his students. He points out that Mme. Curie's comprehensive treatise *Traité de Radio-activité* appeared as long ago as 1910, whereas Prof. Russell's, which appeared in 1922, includes later work and contains more mature views regarding the many phenomena associated with radio-active changes.

The book commences with an introduction on the minerals containing uranium and thorium and an outline of the historical development of the subject. The Rutherford-Soddy disintegration theory, atomic numbers, modern views concerning the structure of the atom, isotopes, and the types of radio-active change are all described as in the original. The following chapters give an account of the analytical chemistry of uranium and thorium, and the last two chapters are devoted to the methods of isolating the radio elements, their use as extremely sensitive indicators, and their detection in minute quantities.

Since Prof. Russell's book appeared, additions have been made to the knowledge of radio-activity, especially on the physical side, but these have scarcely necessitated any deviation from the original text during the translation. The recommendations of the International Commission for Atoms and Atomic Weights (1923) regarding the terms and symbols of the radio-active constants have been followed.

The translation should prove as useful to Czech students as the original has been for the English-reading ones. J. G. F. Druce.

GEOLOGY

Useful Aspects of Geology. By S. J. Shand, D.Sc., Ph.D., F.G.S. (Pp. x + 197, with 23 figures.] (T. Murby & Co., 1925. Price 7*s*. 6*d*. net.)

This little book, according to Prof. Shand's preface, is "offered to the large class of people who have never picked up any systematic knowledge of geology, and who are interested, whether as landowners, shareholders, prospectors, engineers, builders, miners, farmers, or perhaps, just as lookers-on, in one or other of the many undertakings that depend for their success on the application of geology." The Scylla and Charybdis of this kind of effort are, as Prof. Shand says, the danger of making the subject so difficult as to scare the reader, and of making the presentation in such simple terms as to have no real educative value at all. We think that Prof. Shand has successfully steered a middle course, and that, if the classes of readers mentioned above do peruse his book with ordinary attention, they will arise with a very fair grasp of the subject.

The book includes chapters on geological age and structure; the eruptive rocks and mineral deposits connected with them; weathering, soil, sediments, and sedimentary rocks; the metamorphic rocks; building materials, water-finding, oil geology, and some engineering problems. The writing is very clear and simple, and the mode of presentation will suit the public the book is designed to reach. The table on p. 58 may perhaps mislead the uninstructed reader in view of what follows in the next chapter; and the statement that the diamond still furnishes the only example of a payable dissemination in an eruptive rock (p. 73) is incorrect, for the disseminated copper ores in certain eruptive rocks of Western America are certainly paying propositions.

This book is excellently done, and will do much to popularise geology amongst those people to whom the science is of business or professional interest.

G. W. T.

Coal and Civilisation. By E. C. Jeffrey, Ph.D., S.D., LL.D. [Pp. xvi + 178, with 44 figures and 1 plate.] (New York: The Macmillan Co., 1925.)

This book combines two very different aims. It directs the general reader to coal, with its products and their uses, as the basis of our civilisation; and it presents a simply-written account of the composition, structure, and origin of carbonaceous rocks. The author's view is that abundance of coal, with its concomitant of easy iron smelting, lies at the foundation of modern life. He thinks that the supplies of oil and natural gas are too ephemeral and uncertain to have much effect on the general economic situation, and it is therefore unwise of nations to risk war for the sake of oilfields.

In regard to the origin of coal, Jeffrey holds that the great mass of coals have essentially the same mixed composition, and differ from one another merely in their varying proportions of modified wood, burned wood, spores, and dark, structureless matrix. He lays great stress on the preservative action of water and of fire (charring) on vegetable matter, and its disintegration to a structureless mass when exposed to the atmosphere and biochemical processes of decay. The theory of the detrital origin of coal thus finds in this author a convinced advocate.

Jeffrey is, however, scarcely fair to geologists in his strictures on their theories of the origin of coals. He states that the fundamental problem of the composition and structure of coal is one quite beyond the usual geological methods, and that the palæobotanist is best able to illuminate this dark subject. This may be; but the study of its paragenesis is surely essential to the right understanding of the problem of the origin and modes of accumulation of coal, and this is where the geologist comes in. The decisive rejection of the theory of the algal origin of bogheads, torbanites, certain cannels, etc., in this book, shows that the palæobotanical method is not infallible; for it has been recently shown that oil-rich algæ do exist, and that their dried and hardened remains make up an organic mineral (coroongite), the structure and composition of which is identical with that of many boghead coals.

Notwithstanding its rather confident assumptions and pronounced advocacy, this book stands out as one of the best statements we have on the present position of theories of coal origins, and on the economics of the rivalry of coal and oil.

G. W. T.

BOTANY

A Textbook of General Botany. By Prof. W. H. Brown. [Pp. xi + 484, with 518 figures.] (London: Ginn & Co., 1925. Price 13*s.* 6*d.* net.)

It is refreshing to find a textbook of Botany in which the author has departed from the hackneyed material upon which most figures are based. Most of the plants employed for illustrative purposes in these pages are such as occur in the Philippine Islands, of the University of which the author is Professor of Botany. The illustrations are both clear and well chosen, but, unfortunately, their utility is considerably depreciated by the infrequency of annotated lettering.

The text is clear and generalised in character, in parts perhaps somewhat cursory, and deals in turn with the various organs of the plant, their morphology, structure, and physiology; a blending of the various aspects of the subject which adds both to the interest and educational utility of the text. Each chapter is subdivided into headed paragraphs, which arrangement, though facilitating reference, results in a somewhat staccato treatment.

The concluding third of the book is occupied with a consideration of the plant groups, which are treated from the general viewpoint rather than from that of particular types. There are also short chapters on Plant Geography and Heredity.

The ground covered is that of an elementary course, but the emphasis on the various aspects of the subject differs slightly from that found in most European textbooks. E. J. S.

The Vegetation of Burma from an Ecological Standpoint. By L. DUDLEY STAMP, B.A., D.Sc. (Lond.), A.K.C., F.G.S., I.E.S. [Pp. vi + 58, with 41 illustrations.] (Calcutta: Thacker, Spink & Co., 1925. Price Rs. 7.)

THE study of vegetation in the different regions of the earth is regarded as a matter of such importance that a work dealing with so interesting a country as Burma must command special attention.

The vegetation of Burma has already been described in greater or less detail in numerous publications. Kurz's *Preliminary Report on the Forests and Vegetation of Pegu*, published in 1873, dealt with a limited portion of what is now comprised in the Province of Burma. Since Kurz's day descriptions of the vegetation of particular tracts have appeared at various times and in different publications, and in particular the numerous working plans prepared by officers of the Forest Service contain a vast amount of descriptive detail. The author has availed himself of data obtained from these different sources, which he has supplemented from personal observations during tours made in various parts of the country from 1922 to 1924. The result is a work which, though by no means exhaustive, gives an outline of the vegetation of the country which is designed to serve as a basis for future ecological work.

Dealing with the effect of elevation, the author notes that there is a marked change in the vegetation on reaching the 3,000-foot contour line, above which the frost-tender trees of the lower levels give place to oaks, castanopsis, pines, and other trees of the mountain forests.

The typically monsoon climate of Burma is characterised by a rainy season from June to September or October. The author follows previous writers in recognising two rainfall lines of paramount importance; one, the 40-inch line, separates the scrub and thorn forests of the dry zone of central Burma from the economically important monsoon forests in which most of the trees lose their leaves in the dry season; the other, the 80-inch line, which is perhaps less well marked, separates the monsoon from the tropical evergreen forests.

As might be expected in a book written by a geologist, the importance of geology and the resultant soils as the controlling factor in the local distribution of forest types is fully recognised; the relation between geology and vegetation is dealt with in a lucid and well-reasoned manner, and is well illustrated by a series of sketch maps.

The bulk of the book is taken up with a description of the various types of vegetation, for which purpose a provisional classification is put forward in which thirty-five different types are recognised, these being grouped into three main heads: (1) Mountain vegetation (above 3,000 feet); (2) lowland vegetation (below 3,000 feet); (3) seral communities, *i.e.* types which have not reached the natural climatic climax for the locality in which they occur. Doubtless the proposed classification will be found capable of modification as the vegetation of Burma comes to be studied in greater detail and the important questions of succession and the action of man are more fully taken into account. Bracken brake and bamboo brake, for example, are due to a very considerable extent to the effect of temporary forest clearings. The types described will be readily recognised by anyone acquainted with Burma, and many of them conform to the types described by Kurz and other writers.

The book, which is well illustrated with photographs, sketch maps, and sectional drawings, may be commended to those who are interested in vegetation study, and will be found to be a useful guide to those who contemplate ecological studies in Burma. R. S. Troup.

Genetics in Plant and Animal Improvement. By D. F. Jones. [Pp. viii + 568, with 229 figures.] (New York: John Wiley & Sons; London: Chapman & Hall, 1925. Price 20*s*. net.)

The rapid advance in the science of genetics has led to such an overwhelming flood of literature on the subject that the agricultural student and general reader are rather in the unfortunate position of being unable to see the wood for the trees, a fact which renders the appearance of this volume most opportune. It is intended primarily as a textbook for the first course in genetics, and succeeds admirably in drawing a clear outline of the present position of the science, with indications of the various conflicting theories and of the application of genetical methods to the problems of plant and animal improvement. Of necessity much important work is omitted, but enough is included to bring out clearly the close association between theory and practice.

The earlier chapters are devoted to a reasoned argument of the benefit that may accrue from the application of genetics to agriculture and to a comparison of the relative importance of inheritance, environment, and training. Following on an exposition of the fact that greater variability is induced by sexual reproduction than by asexual methods, the cytological aspects of inheritance are discussed and the value of mendelism to the plant and animal breeder is strongly upheld. The question of linkage is explained in some detail and well illustrated, different theories of sex determination are examined, and variations due to modifications, combinations, and mutations are described. A most useful chapter deals with the statistical measures of variation and correlation, general formulæ and short methods being set out and illustrated by examples, and the appropriate application of the different methods and formulæ being indicated. A considerable amount of space is devoted to the question of inbreeding, the author's ultimate conclusion being that close mating in itself is not injurious, but that " the only injury which may proceed from inbreeding comes from the inheritance received." He claims that inbreeding can be used to purify a cross-bred stock of undesirable characters, and the resulting loss of vigour be remedied later by suitable crossing. If this improvement can be fixed, then " inbreeding is not only not injurious, but is highly beneficial and should be given its rightful valuation as an actual means of plant and animal improvement." After a consideration of the problem of sterility the deduction is made that rigid inbreeding is the only certain cure for sterility due to impotence, but that this method is doomed to failure where sterility is due to incompatibility. The last two chapters deal with practical methods utilised in plant and animal improvement, and are intended to provide an introduction to more comprehensive textbooks on the subject. A glossary, bibliography, and index round off a volume that should prove as valuable to workers in this country as in America. W. E. Brenchley.

ZOOLOGY

Evolution in the Light of Modern Knowledge. A Collective Work. [Pp. xiv + 528 (including index), with 4 plates.] (London: Blackie & Son, 1925. Price 21*s*.)

Contents and Contributors.—Chapter 1: " Cosmogony," by James H. Jeans, M.A., D.Sc., F.R.S. Chapter 2: " The Evolution of the Earth as a Planet," by Harold Jeffreys, M.A., D.Sc. Chapter 3: "Geology," by William W. Watts, Sc.D., F.R.S. Chapter 4: "Biology," by Conwy Lloyd Morgan, D.Sc., F.R.S. Chapter 5: "Botany," by Frederick O. Bower, Sc.D., D.Sc., F.R.S. Chapter 6: "Zoology," by Ernest W. MacBride, M.A., D.Sc., F.R.S. Chapter 7: "Physiology," by Marcus S. Pembrey, M.A., M.D., F.R.S. Chapter 8: "Anthropology," by G. Elliot-Smith, M.A., M.D., F.R.S. Chapter 9: "Mental Evolution," by William M'Dougall, M.B., F.R.S. Chapter 10: "Physics and Chemistry," by Frederick Soddy, M.A., F.R.S. Chapter 11: "Time and Space," by Alfred A. Robb, Sc.D., D.Sc., Ph.D., F.R.S. Chapter 12: "Philosophy," by A. E. Taylor, M.A., D.Litt. Chapter 13: "The Religious Effect of the Idea of Evolution," by the Rev. James Maurice Wilson, D.D., F.G.S.

Two years ago the reviewer, then *in statu pupillari*, was spending some of his leisure in reading the works of Charles Darwin, Herbert Spencer, T. H. Huxley, Laplace, Norman Lockyer and other pioneer writers on the subject of evolution: he soon realised, from his specialist knowledge of one section of biology, that at least some important changes in the general outlook had occurred since the time of the Victorian masters. This realisation was to him, as it must be to many others, disturbing, for evidently no statement or formula made by these older masters could be, with certainty, taken as generally or even partially acceptable to living authorities. But were there any authoritative recent statements on these matters in convenient book form? To this question, a widely read and friendly senior could not, in 1923, definitely give an affirmative reply; as a result of this question, Blackie & Son, Ltd., have published the book under review, and they deserve the thanks of all, young or old, clerics or laymen, men of science or otherwise, who believe, with Canon Wilson, that "evolution is now no longer a mere theory which those who deal with eternal truths can ignore as destined to pass away." We have now a volume which, first, will help us to read the old masters with discrimination as well as delight; second, will condense the diffuse information which many of us acquire by desultory reading, conversation, and attendance at the meetings of learned societies.

This book might well have been titled, "Genesis as pictured in 1925." Some parts of the story, dealing with recently discovered phenomena and lately conceived ideas, are really awe-inspiring; read: "the writer had suggested that the total annihilation of matter would provide a possible and adequate source of stellar energy," and "as the result of millions of millions of years of emission of radiation, our sun has shrunk to his present moderate dimensions. Sometime during this span of . . . years a wandering star came so close that our sun, unable to stand the intense tidal forces generated, broke into pieces, and out of the debris our earth and moon, as well as all the other planets and their satellites, were formed," and "planetary systems . . . must be fairly freely scattered in space." These extracts are all from the masterly essay on "Cosmogony," but other sections are equally productive, although, to the non-botanist, the chapter by Prof. Bower may present nomenclature difficulties; and certainly the reviewer does not "presume to understand" the essay on "Time and Space," in its entirety, but notes with relief that there is "no incompatibility between the views which we have here expressed as to the nature of time and space on the one hand, and the view of evolution as being a real development on the other."

We know that these statements are, in this book, made by authorities who have given many years of their lives to the critical thought and experimentation on the subject-matter in their chapters. So the educated reader, will feel a sense of satisfaction in reading this version of Genesis, in which, apparently, there is already a degree of permanency about certain of the clauses. Read: "There is no longer any doubt that man is descended from a series of anthropoid apes whose Miocene forerunner was also the ancestor of the gorilla and the chimpanzee. It is also certain that for a vast period of time—perhaps even millions of years—men lived upon the earth without attempting to devise any of the arts and crafts or customs and beliefs that form the constituent elements of civilization" (Elliott Smith), and, "In one case, however, we have more positive evidence of the existence of evolution, or, already indicated, devolution of the chemical elements than any that has yet been obtained for organisms, and that is in the case of the radio-active elements" (Soddy), and: "the parallel between the evolution of brain and the evolution of mental functions seems to be clearly made out, in general terms, as a rule without exceptions" (M'Dougall).

Many quotations, from the different essays, might be made to show that a new Genesis written in 1926 might be very different from that under review. There is, in 1925, an evident tendency for many of the essayists to flirt with Prof. Lloyd Morgan's fascinating ideas on emergent evolution, which he outlines in his essay on Biology; but Prof. Lloyd Morgan, very fairly, also presents the views of the mechanists, and the Hormists: what will emerge from this conflict? The philosopher warns us that science can never reach finality in its hypothetical explanations. "So far as it (Science), can be said to achieve finality at all, it achieves it in its denials, not in its affirmations. Thus, we may regard the work of Darwin as final on its negative side. It definitely negatives the conception of 'kinds' as constants fixed once and for all. On the positive side Darwin's, or any other, hypothesis about the precise factors which determine the origination of a 'kind,' and their relative importance, is always open to revision" (Taylor).

I desire particularly to mention the essay by Canon Wilson of Worcester, who in November 1859, when Darwin's *Origin of Species* was first published, was already the science master at Rugby School. In this charming and helpful essay he tells us of the development of his personal religion from the days when "Darwin seemed to have almost dispensed with a Creator, or, at least, thrown Him back into the infinite past." Here is a diary of a mind during a transition period in the history of Christianity. How many of our graduates, fresh from biological schools, still suffer from mental conflict of the same order as that which this essay records? Here, there is sympathy with and assistance for them.

THE YOUNG FRIEND.

Concerning Evolution. By J. ARTHUR THOMSON, M.A., LL.D. [Pp. xi + 241, with 25 figures.] (Oxford: at the University Press. Price 11*s*. 6*d*. net.)

THIS very readable book is based on a series of lectures delivered at Yale University in 1924. It is an excellent résumé of modern views of evolution in all its bearings. It is written in a clear and simple style that makes it quite understandable of non-biological readers. The writer, moreover, takes up a very sane attitude to the relation of modern biological science to religion. He states as the general idea of evolution that the present is the child of the past and the parent of the future. The underlying sense of moral responsibility thus disclosed is fundamentally altruistic in its highest sense, and affords a sound biological basis to the highest form of religion. Dr. Thomson considers it an impiety and a denial of our birthright as inquiring minds to be satisfied with the transcendental answer to the inquiry as to the source of the immense world of living creatures that it has all come by the "Will of the Creator." The more thoroughly we can answer the scientific question, the more truth we shall see in the religious interpretation. On the scientific side, Dr. Thomson stresses the idea of emergent evolution, meaning by emergence a genuine novelty and not a mere additive result. All the great steps in evolution have been of this character, quite unpredictable, just as the properties of water are unpredictable from those of its constituents, oxygen and hydrogen. Particularly does he consider this true of the emergence of man from a Simian stock. Altogether the book is worthy of careful study, not only for its wide scope, but also because it is highly stimulative and provocative of thought. W. C. B.

Evolution, Heredity, and Variation. By D. WARD CUTLER, M.A. (Cantab.), F.R.S. [Pp. 147, with 27 figures.] (London: Christophers, 1925. Price 3*s*.)

IT is difficult to compress within the limits of a 3*s*. volume the essential facts of modern ideas on evolution, and it is easy to criticise the omissions. We think that this little book, which is intended to be of use to higher forms in secondary schools and to give the general reader some notion of the problems underlying both biology and sociology, will fill a useful place at the present time. It contains eleven chapters, each of which is divided into headed paragraphs. The first two chapters explain what is meant by evolution, and the evidence from various aspects is shown by well-known examples. The evolution of the feet and teeth of the horse is taken as a familiar instance from palæontology. At the present day there is so much divergence of opinion as to the time taken for the stratified rocks to be deposited, that it is hazardous to give even an approximate age for the geological eras; the most recent calculations, based on radio-activity, would make the respective number of years about twenty times greater than that quoted on p. 17. Although the available space is limited, some indication might have been given of the extent of recent discoveries of fossil man. The conception of parallel lines of evolution or orthogenesis might also have received some mention from both geological and anatomical sides.

Two chapters are devoted to early ideas of evolution and to a more detailed account of the theory of Darwin and Wallace in particular. The lucid explanation of Mendelian Inheritance is admirable. The simple structure of the cell is described, and the process of cell division demonstrates the part played by the chromosomes in heredity; the importance of the cytoplasm in this connection is not forgotten. Then follows a most interesting summary of the main problems of the inheritance of sex. It is disconcerting for the uninitiated to come across the word *mutation* (p. 102) fifteen pages before the definition of the term on p. 117. A somewhat similar criticism might be made with reference to the name of *proteus*, which is brought in on p. 113, a name which is quite unknown to the ordinary reader.

The different types of variation are outlined and their effect on evolution shown, and in a short chapter is given an epitome of statistical methods of heredity. In summing up, the author makes no allusion to the fact that much of the experimental evidence—for example, the breeding of Drosophila—is carried out under necessarily artificial conditions, and cannot, therefore, be relied upon to show us the exact conditions occurring in nature.

This book, which is written in clear and simple language throughout, is a most successful introduction to the present position of recent research on evolution, heredity, and variation. E. A. F.

MEDICINE

Health and Environment. By LEONARD HILL, M.B., F.R.S., and ARGYLL CAMPBELL, M.D., D.Sc. [Pp. 208 + x, with 7 plates and a chart.] (London: Edward Arnold & Co., 1925. Price 12*s*. 6*d*. net.)

THE authors are to be congratulated on the manner in which they have embodied in one volume the main results and substance of their reports on "The Science of Ventilation and Open-air Treatment" and "The Kata-thermometer in Studies of Body-heat and Efficiency." The book deserves to be widely read by all who are interested in the improvement of national health. As the authors say in their preface, it is such information as they have brought together, which means so much to the welfare of those at work in factories, etc., that is seldom or never met with outside medical journals or official reports. The chapter on ventilation is particularly good, and the uses of the kata-thermometer are clearly explained. As the authors advise, whatever means of ventilation are provided, it should be someone's special duty to attend to the same. Under no circumstances should the old bronchitic male or weak anæmic girl, both with a horror of fresh air, dominate the ventilation and heating arrangements for a hundred or so healthy persons, as is unfortunately only too often the case. One has only to pass the dwellings of the poor in the autumn or winter and see every window in their houses tightly closed, and when it is remembered that several families are living crowded together with several human beings in each room, it is not difficult to imagine how easily infectious diseases can be disseminated. The question of ventilation in factories, cinemas, and other places where people congregate is so important that no building which is designed to accommodate large numbers of people should be allowed to be erected before it has been proved to be efficiently ventilated. These are the places, particularly in the winter months, where colds, coughs, influenza, and respiratory diseases are disseminated. They are usually over-heated, and when it is found necessary to cool them, blasts of cold air are driven in at the body level instead of high up, well above the head level.

The reviewer has proved in his own household by keeping windows and doors in all bedrooms open winter and summer that all the members are not only freer from colds and coughs, but that their general health is much better. The circulation of fresh air is essential to good health, and even the baby of a few months is the better for it, but nurses and others who have for years been accustomed to sleep in rooms with windows tightly closed at night do not find it easy to overcome their bad habits or prejudices.

The kata-thermometer is the instrument now used for detecting any error of ventilation in enclosed spaces. Since its introduction much has been done, but still more can unquestionably be done, to improve the air circulation in factories, laundries, and mines, resulting in the marked improvement of the health of the workers. Education has done more perhaps than any other factor in lowering the infant mortality in urban districts. It should be conducted by cinemas and well-illustrated lectures. The great advantage of open spaces, sunlight, less crowding, particularly in the case of the children, and cleanliness should be taught.

We have learnt much from heliotherapy of recent years. Not the least remarkable phenomenon is the manner in which young subjects can stand high altitudes without a shiver, when exposed to the sun's rays, which by slow exposures increase the pigment and thereby do away with the necessity for clothing—this even when they are the subjects of surgical tuberculosis and are fixed in their beds in splints. The authors give some interesting photographs, which tell their own story. In this country, unfortunately, it is difficult to find any locality where there is sufficient sunshine, as in the Swiss Alps, to benefit the young sufferers, and the sun has largely to be replaced by arc-lamps. Over-exposure is dangerous, and sunburn has to be carefully avoided. Treatment by heliotherapy has been found to be of little avail unless the patient's mind is occupied by congenial employment.

It is not possible in a short review to touch on all the important subjects dealt with by the authors in this admirable little book, which should certainly be read and re-read by all school teachers and others responsible for the health of those under their care.

R. E. DRAKE-BROCKMAN.

Lister and his Achievement. By Sir Wm. Watson Cheyne, Bt. [Pp. 136.] (London: Longmans, Green & Co., 1925. Price 7*s.* 6*d.* net.)

The first Lister Memorial Lecture delivered at the Royal College of Surgeons of England takes up the first thirty-eight pages of this book, while the remainder consists of the Appendix, in which the author gives a more detailed account of the progress of Lister's work and his investigations, together with some of the author's own views on antisepsis.

It matters little, except from a historical point of view, who actually was the first to perform or resuscitate any particular operation—the great fact remains that Lister was the master-mind that made all operations possible and rendered them less dangerous. Henceforward, surgeons became bolder and prognosis became brighter. Any anecdotes of Lister will always be welcome from any of the fast-disappearing band of pupils who followed him through his wards and were eye-witnesses of his wonderful work during his earlier struggles, and later, when he was at the zenith of his fame and his name was a household word throughout the civilised world. Of Lister's early assistants only two, Sir Hector Cameron and the author, are still with us.

A good deal of the Appendix is mere repetition of what has been said in the Lecture, and might well have been left out. However, surgeons of to-day and to-morrow will be grateful to the distinguished author for his valuable addition to our knowledge of the father of modern surgery.

R. E. Drake-Brockman.

The Bacteriology of Food. By Cuthbert Dukes, M.D., M.Sc., D.P.H. [Pp. x + 180.] (London: H. K. Lewis & Co., 1925. Price 7*s.* 6*d.* net.)

There are few branches of biology that concern so many departments of human interest as the study of bacteria. In its earlier development, bacteriology was almost a branch of pathology, since the micro-organisms producing human disease engaged the lion's share of attention. A specialised technique for investigating the problems presented by pathogenic bacteria was consequently developed. More recently the study of micro-organisms has been greatly widened by the recognition of their importance in such fields as soil fertility, plant diseases, dairying, water hygiene, sewage purification, and in connection with certain industrial processes. At first it was natural that the specialised technique already developed for the study of pathogenic forms should be applied in these new fields of investigation. Soon, however, the need for new methods of research especially suited to each new subject were found to be necessary, so that there have now arisen new branches of bacteriology each with its own methods of investigation. This is well illustrated by Dr. Cuthbert Duke's book, which gives an admirably lucid account of the relation of bacteriology to food and food hygiene. His subject covers the bacteriology of water supply, of milk, butter, cheese, and other milk products, and of food preserved by cold storage, "canning," and fermentation. The general scheme followed in the treatment of each subject is to describe first the sources of infection and the general types of micro-organisms occurring in each type of food, and then to discuss the technique used in their investigation and the methods employed in practice to control the bacterial population and to eliminate pathogenic forms.

In many forms of food, such as fresh milk, complete sterility is not practicable. The problem is rather to control the total numbers of organisms present and the relative number of harmful forms. In bacteriological tests of food purity, therefore, quantitative methods assume a vital importance. Estimates of bacterial numbers are usually based on counts of the colonies developing on agar or gelatine platings, made from a diluted suspension of the food. To achieve accurate results by this technique, a number of parallel platings of each dilution are necessary to reduce the error due to the random distribution of bacteria in the suspension, and often increased by interference between colonies on the plates. The standard plating technique described in this book shows that the need for this is not generally recognised, even though this need has been demonstrated by statistical work on soil bacteria and by such work as that of Breed and Stocking on counts of bacteria in milk.

Dr. Dukes gives excellent advice as to methods by which cleaner milk may be produced. In this connection the importance of cleanliness in the cooling machine should be emphasised, and the growing importance of the tuberculin testing of cattle justifies a reference, in the next edition, to the recent report of the Medical Research Council on the various methods of carrying out this test.

H. G. THORNTON.

Medical Education: A Comparative Study. By ABRAHAM FLEXNER. [Pp. xi + 334.] (New York: The Macmillan Co., 1925. Price $2.50.)

IN this comprehensive survey of medical training Dr. Flexner has presented those organisations responsible for educating the medical student with much food for thought. After wandering through the mazes of regulations, traditions, and actual conditions of to-day it would scarcely be surprising if a volume of administrative statistics was the sum total of his daily interviews and inspections.

This is fortunately not the case. Comparisons of curricula, equipments, and costs are bound to be enumerated to a certain extent, but the author has set forth with a few basic principles in his mind as to what constitutes true education, and in every medical school of Europe and America he has verified the presence or absence of these guiding influences. Of details he has retained sufficient to give the reader a picture of the type of teacher, student, equipment, and of end-results of the systems organised, namely, the doctors trained and research work produced, while allowing for national characteristics, which are bound to influence any training centre. It is scarcely possible to compare in scientific detail the training, for example, of a doctor who is to minister to the far west of America and that of the scholarly investigator of Germany or the older British Universities. Dr. Flexner is well aware of this, and is content to describe things as they exist, and, not without caution, as he might desire them to exist. This renders the book useful for the reformer who wants clear information. Apart from description, Dr. Flexner unhesitatingly praises the systems which he considers most fruitful. He is, for instance, emphatic that pathological institutes with research facilities should not merely be in the medical school but actually attached to every hospital; or, again, he contrasts the London bio-chemical and physiological laboratories, where most students can perform experiments with sufficient fumbling to learn, with the dull materia medica lectures to which some countries submit their students for exercises in memory. "Every student can learn more than he can be taught," he writes, and surely all would-be crammers and examination fiends should take this "dictum" to heart.

Dr. Flexner concludes with a sympathetic chapter on the question of costs, with which problem his country are dealing so practically, and are yet methodically encouraging the systems they approve. Every further step in outlay must make a good case, though excessive caution may kill. "Research," he writes, "involves risks and waste." In general, the forward movement in the financing of medical education and research is to be regarded as a triumph and inspiration. We agree, and are grateful.

R. VERNEY.

The Engines of the Human Body. By SIR ARTHUR KEITH, D.Sc., F.R.S. [Second Edition. Pp. xvi + 343, with 47 figures.] (London: Williams & Norgate, 1925. Price 12*s.* 6*d.* net.)

To Sir Arthur Keith we are once more indebted for a new series of stories which together make up the volume *The Engines of the Human Body.* Here the very least of us may read and ponder on some of the marvellous engines which are welded together in "Nature's master contrivance." For many Christmases children and adults alike have been privileged to hear lectures at the Royal Institution on the human machines, and to see models and imitations of such mechanisms as the leverage of the foot actually working before them. Though muscular action is commonly placed in the province of anatomy we cannot but feel that distinction between living anatomy and physiology no longer exists. When we turn to the description of bone development, to Professor Keith's apt comparison of muscles with the engines of a motor-cycle—a certain means of attracting small boys as well as the inquiring student—to his picture of factories where tissue fuel is prepared, or to his analogy between the one-roomed houses of Highland Crofters and the animal of low order with little specialisation of its parts, we are delightedly and lucidly impressed. The story of Harvey's boyhood questioning, culminating in his revolutionary discovery of the circulation, is couched in vivid and picturesque language; many other historic contributions to our present-day knowledge are given in stirring fashion. The book is no mere history—any medical student on the eve of studying the intricate mechanisms of our nervous system would do well to read Keith's description of the body's telephone system. In the appendixes likewise can be found most lucid summaries of recent researches on the needs of athletes, output of the heart, breathing, thinking, the mechanism of oxygen supply in view of the Peru Scientific Expedition findings, vitamins, the origin of petroleum, and many other novel researches, all of which make the volume a real possession and stimulus to thoughtful investigation.

R. VERNEY.

Medical Sciences in the German Universities. By THEODOR BILLROTH. [Pp. xiii + 292.] (New York: The Macmillan Co., 1924.)

THEODOR BILLROTH, pioneer surgeon of Vienna, must be known and revered by a generation of medical students throughout Germany and Austria. Thanks are due to Mr. Welch for this able translation. The English-speaking world of medicine may now peep into the mind of this charming professor, and will without fail derive fruitful ideas on the value of different curricula for training and educating the young doctor from it.

Half a century ago, modern medicine, public health, and social applications of science were thought of in casual fashion, were dreamed of by a few, but were hardly conceived to be practical politics. Billroth's view was ahead of his time. He describes his initial struggle as the new professor at Vienna as that of an *enfant terrible* among the senior staff. Mere biography this volume is not. We have an accurate and vivid history of the growth of various subjects which medical students used to pursue. The difficult and wavering transition of medical sciences from the realms of superstitious art to the detailed conclusions of modern experimentalists is traced with enormous patience. We have history sympathetically penned, no less courageously was Billroth emphatic enough to obtain his ends, and these were clearly inspired by a deep sense of patriotism—an aim to make the doctor finest of all citizens.

If we are to criticise, we should remark on his insistence upon a basis of wealth as a preliminary for study. The struggle of the poverty-stricken student has clearly impressed Billroth as being of doubtful success. Are the ascending roads for the brilliant poor student so much more narrowed in Germany than elsewhere? There is little discussion of scholarships or other aids to the impecunious. Again, the proportion of State help rendered to the profession is contrasted with that prescribed for the army. It is a little difficult for the non-German to pass the statement that compulsory service is of high cultural value, knowing what standards of personal and civic culture Billroth himself possessed and inspired in others. He fears that without military restraint, clamour for individual rights would bring a reversion to primitive conditions, in which the strong would be strengthened and the weak enslaved. Is this borne out by the progress of culture in other countries? And has militarism advanced the development of German science beyond all others? Surely the scientific spirit of Germany has proved strong in the depths of military weakness? Its force has survived all military failure. Does not modern Germany acutely realise that, rich or poor, it is only through the unfailing pursuit of the highest art and science that the soul of a nation can ally itself with the greatest ideals of peace and national prosperity? We could wish Billroth were alive now.

R. VERNEY.

MISCELLANEOUS

Structural Engineering: Strength of Materials. By G. F. SWAIN. [Pp. xi + 569, with 468 figures.] (London: McGraw-Hill Publishing Co., 1924. Price 25*s*. net.)

THIS volume is the first to be published of a series of four.

The present volume and a second are devoted to the Strength of Materials, treated especially in a manner necessary for the consideration of the Design of Structures.

The last two volumes are to be devoted to Structures, one of them relating to the simple types in wood, metal, and masonry, while the other will deal with Indeterminate and Complex Structures.

The author has thus set himself a very comprehensive task, and we look for the remaining three volumes with interest. This book is very complete so far as it goes, and the author rightly suggests that selections from it, which he indicates, may be passed over by many readers.

A summary of necessary mechanical principles and another of geometrical relations begin the work.

The treatment of stresses and strains is unusually complete for an engineering book.

The author's comments on certain optical methods for deducing stresses form a suitable subject for a very considerable debate, the mixture of praise and incredulity being quite frankly blended in a somewhat amusing manner.

The treatment of the stresses in beam sections and the ellipse of stress is also unusually thorough, while slopes and deflections are very fully treated.

Both continuous beams and hooks are given rather cursory treatment.

Riveted joints and columns are fully dealt with. Some very interesting matter is given in connection with testing under both ordinary loads and repeated loading.

There is a breezy chapter (24) on Mathematics and Common Sense, which ends the book. The author, in places, draws on his large practical experience in an illuminating manner.

There are several slips: for example, in the equation on p. 248 and twice on p. 558 we find the name of Prof. Karl Pearson wrongly spelt.

On the whole, the book makes very interesting reading and it can be recommended to the more advanced student of the subject.

H. T. D.

Oscillographs. By J. T. Irwin. [Pp. xii + 164.] (London: Sir Isaac Pitman & Sons, 1925. Price 7*s*. 6*d*. net.)

The author, as he explains in his Preface, has set out to provide a book which shall describe the construction and theory of the different types of instrument at present in use in such a way as to be intelligible to the engineering student. To that end, a large part of the book is taken up by very complete mathematical expositions, starting practically from the first principles of electro-magnetism. One has no right to quarrel with an author who fulfils his set task as Mr. Irwin very ably does, but one feels it is a pity that he has not given more technological details of the apparatus and practical hints in the measurement of a wave-form in a simple case, like that of an alternator. The author's own contributions to the technique of wave plotting are included, notably his Hot Wire Oscillograph and the Resonant Shunt, which obviates the use of oil for damping. A special chapter is devoted to the Cathode Ray Oscillograph, commencing with the simple theory of perpendicular electrostatic and magnetic fields. The book has apparently been written just too early for the inclusion of the Piezo-Electric instrument of Mr. Wynn Williams, of which details have been published this year (*Phil. Mag.*, Feb.). There are two minor points in the use of symbols liable to cause confusion: in fractions v stands both for voltage (V) across, and velocity of the wire; while B is used in place of the more usual H for intensity of magnetic field. The book is copiously illustrated with vector diagrams and wave records, and with the numerical examples which appeal to the technical student.

E. G. R.

Choosing your Life-work. By William Rosengarten. [Pp. xxii + 323.] (London: The McGraw-Hill Publishing Co., 1924. Price 12*s*. 6*d*. net.)

The author's object is to present in plain and non-technical language a simple and effective plan, whereby the individual may analyse his own capacities, aptitudes and interests, compare them with the requirements of representative occupations and plan his career accordingly.

Though this work as a whole will be of interest to English readers, especially head masters, its usefulness is somewhat limited by its application to American life and society. It is true that most of the conditions determining fitness for a particular career are alike in all countries, but the demands of the Societies controlling the various professions and trades vary widely. Even the questionnaire for self-analysis is strange to English readers, *e.g.*:

Do you "get-by" in school with little or no study, or do you have to "plug hard" to pass?

Are you timid, a "go-getter," or neither?

Are you a "good-mixer."

W. C. B.

Civilisation and Climate. By Ellsworth Huntingdon. Third edition, revised. [Pp. xix + 453, with 48 figures.] (New Haven: Yale University Press; London: Oxford University Press, 1924. Price 23*s*. net.)

This book contains two main lines of investigation which at heart deal only with a single problem. First, there is an inquiry into the relationship between climate and the bodily and mental activity of man, *i.e.* between climate and civilisation. Secondly, there is an inquiry into the climates of the civilised lands of antiquity, in which the author postulates a pulsatory theory of climatic change in consequence of which, *e.g.*, Egypt, Greece, Italy possessed climates more favourable to bodily and mental activity in classical times than at the present day.

In the section dealing with climate and health there is a considerable amount of new material, especially in relation to the effect of humidity; and, although the evidence is conflicting, it seems to prove that humidity is beneficial in its direct effect with temperatures below about 64° F., and is harmful with temperatures above that figure, while its indirect effect is always injurious, as it facilitates the transmission of harmful micro-organisms. The question of the influence of light on health still receives scanty treatment, in spite of Woodruff's important work on the subject. Indeed, Huntingdon ignores Woodruff's contention that it is the intensity of the light that is harmful to White Man in the Tropics; he deals with the problem only in regard to extra-tropical America, and then only in respect of the length of the day!

The section dealing with climate and civilisation is also much fuller, and includes two completely new chapters, one dealing with Aboriginal America and Modern Australia, and the other providing a convincing refutation of the charges brought against Huntingdon's Pulsatory Hypothesis. The first-mentioned of these chapters shows clearly that the author does not consider climate to be the only factor in determining the distribution of civilisation. By insisting, in this new edition, less strongly on the direct influence of climate and more strongly on racial inheritance and cultural equipment, Huntingdon to a large extent disarms criticism, and, by urging that civilised man in early times was less well equipped materially to combat the difficulties of cool climates, he almost completes the disarming process. If, in addition, Perry's theories of the distribution of culture were taken into account, an explanation might be found, in accord with Huntingdon's own theory of "cultural development," for the puzzling Maya and Inca civilisations, to which none of Huntingdon's explanations supply an adequate key.

Space forbids further discussion of this extraordinarily provocative book. It is emphatically a book to be reread. It is as stimulating to mental energy as the most stimulating climate it describes!

M. Shackleton.

Historic Instruments for the Advancement of Science. A Handbook to the Oxford Collections, prepared for the opening of the Lewis Evans Collection on May 5, 1925. By R. T. Gunther. [Pp. iv + 90.] (London: Oxford University Press, 1925. Price 2*s*. 6*d*. net.)

The Lewis Evans Collection of Historic Scientific Instruments, supplemented by others deposited by Christ Church and New Colleges, constitutes one of the finest available to the public in this country, and the thanks of all students of science are jointly due to Dr. Evans for his generosity in presenting them to the University of Oxford for exhibition, and to Mr. Gunther for his excellent record of their contents. Naturally the maximum benefit from this small book can only be derived from a personal inspection of the instruments housed in the Ashmolean at Oxford. It is not, however, within the opportunities of all who would wish to do so to pay Oxford a visit for this purpose. Nevertheless, we have no hesitation in saying that this handbook is of immense value to all who are interested in the history of science. The evolution of instruments of precision is a big and an important subject, and few are so well qualified as is Mr. Gunther in its exposition. His volumes on *Early Science in Oxford* entitle us to regard his statements in this field as authoritative.

Historic Instruments for the Advancement of Science is not a mere catalogue of exhibits. It is filled with a running commentary of valuable information regarding the history of instruments, much of which is abstracted from the author's *Early Science in Oxford*. Prefaced with an historical record of the Old Ashmolean Building, the book deals consecutively with astrolabes, physical apparatus, orreries, dials, globes, and methematical, surveying, and optical instruments. The book is tastefully produced and includes some illustrations. I. B. H.

An Introduction to Economic Geography. Vol. I. Natural Environment as Related to Economic Life. By W. D. JONES and D. S. WHITTLESEY. [Pp. xxv + 375, with 366 figures.] (Chicago: The University Press. Price $5.)

WE have here another example of the great interest being taken in Economic Geography on both sides of the Atlantic, but more especially in North America. Unlike most of the textbooks on this subject which have appeared recently, however, the work under review is more specifically intended for class use, either in the first year of university work or in the higher forms of schools, and it is actually employed as a complete one-year course in the University of Chicago.

The volume deals with the influence of natural environment, *i.e.* climate, natural vegetation, land forms, etc., on human activity, and more especially on economic activity, and it is to be followed by a more advanced volume stressing the economic activities themselves.

The method of presenting the material is new in that each subject is approached by means of questions and exercises with the object of making the student think for himself. The second section of the book consists of text, partly taken from various other works in the manner of a "Source Book," but largely prepared by the authors themselves. This, together with the third section, consisting of maps and illustrations, enables the student to solve the problems propounded in the exercises. The photographs are excellent, being both typical of the activities they portray and well selected from different parts of the globe, *e.g.* Fig. 115 showing tea on hill slopes, rice on lowlands in Japan; Fig. 92 showing the wool market in Srinagar. The maps also are well chosen, but in several cases lack both scales and co-ordinates, and it seems a pity that the illustrations should be arranged in a single section instead of being distributed throughout the book, so as to occur with their relevant text.

The book should be very useful to the teacher by virtue of its exercises and the excellent way in which questions, text, and illustrations are correlated, but for the teacher in England the emphasis laid on America and the scanty treatment in the text of the rest of the world is a disadvantage. Another drawback is that the cost of the book will make it difficult in England for every student in the class to possess a copy, although it is evidently intended for general class use.

MARGARET R. SHACKLETON.

Life after Death in Oceania and the Malay Archipelago. By ROSALIND MOSS, B.Sc. (Oxon). [Pp. xii + 247.] (Oxford: at the University Press, 1925.)

MISS MOSS has succeeded in writing an extremely interesting and valuable book. She has collected together a mass of information which has hitherto been scattered in many publications, and by so doing she has been able to tabulate and compare the facts. The result is a definite contribution to our knowledge of the peoples of Oceania. The problem of migrations, for example, is materially advanced by her researches, for, though she is cautious in drawing conclusions, it is very evident that her theories are based on sure ground. She has emphasised the inter-relation between ritual and belief, and has shown how each can arise from the other and how each modifies the other. This is very marked in the case of the canoe-coffin, which, though now interpreted as a soul-boat, is "in reality a vestige of migration." The theories as to the position of the other world are shown to have a very definite origin in the methods of disposing of the dead; thus, cave-burial—which is really due to the necessity of hiding the dead from enemies—leads to a belief in an underground other-world. Miss Moss's suggestion as to the reasons why the west plays so large a part in the eschatology of many parts of Oceania is extraordinarily interesting, and shows that a detailed knowledge of all the facts is necessary before any conclusions can be drawn. According to her view, the belief in the western after-world is due to the memory of migration, the soul returning to the land from which the ancestors came; " the western direction leads to a fictitious connection with sunset and the sun," and when this is combined, as in Polynesia, with the deification of chiefs, there arises a complex form of belief which includes an after-world in the sky. Miss Moss is, however, careful to point out when and where the theories of a sky after-world have been influenced by Christianity or Islam. Altogether the book is one which will be welcomed by anthropologists. There is but one fault to find with it. Miss Moss has not yet realised that a clear and easy style adds greatly to the lucidity of explanations. The matter of the book is so good that it is unfortunate to find it often somewhat spoilt by the manner of presentation.

M. A. MURRAY.

The Science and Art of Living. By LEONARD WILLIAMS, M.D. [Pp. 240.] (London: Hodder & Stoughton, Ltd., 1925. Price 5*s*. net.)

THIS book is a slashing attack on meat-eaters, sweet-eaters, and over-eaters. It is admittedly propagandist and didactic, and the critic is to a large extent disarmed by the author's plain and outspoken preface, in which he pleads guilty to repetitions and redundancies and occasional overstatement of his case for a simpler life. It is the custom nowadays to describe us as a C3 nation on the grounds that a large proportion of those who volunteered, and those who later were called up for service, were found on examination to have some physical defect or other. It must be remembered that many of these defects were brought to light and exaggerated by the owners to avoid service, particularly in the front line, although in ordinary life they were capable of the severest strain and hard work. In any case, the great bulk of the disabilities, such as errors of refraction, minor degrees of deafness, flat feet, varicose veins, hernias, etc., were due to the ever-increasing struggle for existence in these islands, where the population yearly mounts up, and the people gravitate towards the cities where the accommodation for them and their families is inadequate and the sanitary conditions often poor, to say the least of it. With regular, plentiful, and good food and a healthy, open-air life, it was soon found during the war years that the physique of the men improved markedly. With the gradual transition from agriculture to industry our habits must change, and the reviewer agrees with the author that the eating of meat as a daily routine is not only unnecessary, but positively harmful. Greed is common not only to civilised man, but to the savage even more so, while animals, particularly the carnivores, are commonly addicted to it. Owing to the habits of civilised man changing rapidly from an active to a sedentary life, it is very necessary that we who are so condemned should regulate our diet accordingly and eat less. Gluttony is not a crime of this civilisation, but is as old as man; but whereas primitive man could only indulge periodically, and in the intervals, whether he liked it or not, was obliged to fast, civilised man finds himself well supplied without physical effort. Certain of the author's statements are open to question. For example: Are disagreeable draughts essential to the genus homo? Was pyorrhœa alveolaris unknown before antiseptic tooth powders came into vogue? Does the Southerner, unlike the Nordic man, wear black or dark blue under a tropical sun? The Latin races certainly feel the heat less in their own countries bordering the shores of the Mediterranean, and consequently wear their usual clothes of a thin texture, be their colour what it may; but whenever they go to their tropical possessions they invariably wear white, which experience has taught them and ourselves is by far cooler than black or any coloured garment.

The book is well written, and contains much sound advice, which is well rubbed in, but will it reach those who are the greatest offenders? Home life is conducive to healthy living, but it is becoming increasingly popular to lunch and dine in restaurants where people insist on having their money's worth, or, in other words, eat more than they require.

There is a printer's error on page 132 in the spelling of Prof. Gowland Hopkins's name. R. E. Drake-Brockman.

Why the Weather? By Charles Franklin Brooks. [Pp. xvi + 310.] (London: Chapman & Hall. Price 8*s.* 6*d.* net.)

This book explains in simple language those weather phenomena of the United States, the physics of which are tolerably well understood. Many common sayings about the weather are also discussed, and those which have some foundation in fact are discussed from the scientific point of view. The book contains also some notes on meteorological instruments, and some excellent photographs of clouds, dew, ice crystals, etc.

Dr. Brooks has certainly produced an excellent popular work, and his success is probably due to a large extent to his wise plan of obtaining the help, on the one hand, of people familiar with popular notions about the weather, and, on the other hand, of the professional meteorologists of the U.S.A. Weather Bureau, who undertook to purge his exposition of the slightest inaccuracies.

The weather of the northern part of the United States resembles that of the British Isles in many ways, but there are important differences due to the great size of the American continent; these are sufficient greatly to reduce the interest of the work for readers on this side of the Atlantic, yet not nearly sufficient to annul it.

E. V. Newnham.

Education in East Africa. Being the Report of the Educational Commission of the Phelps-Stokes Fund to East Africa, 1924. Prepared by the Chairman of the Commission, Dr. Thomas Jesse Jones. [Pp. 407 + Index.] (Edinburgh House Press. Price 7*s.* 6*d.* net.)

This volume is a companion to the Report of the Phelps-Stokes Commission to West and Central Africa in 1920. The report is exhaustive, providing a complete book of reference on the educational work of the regions concerned. It is also a practical guide to the principles that must be followed if a sound system of education in these countries is to be constructed. It bears witness also to the splendid pioneer work of the mission stations in the field of education. W. C. B.

BOOKS RECEIVED

(Publishers are requested to notify prices)

Differential Equations. By H. B. Phillips, Ph.D., Associate Professor of Mathematics in the Massachusetts Institute of Technology. Second Edition Rewritten. New York: John Wiley & Sons; London: Chapman & Hall, 1924. (Pp. vi + 116.) Price 6*s*. 6*d*.

A Practical Treatise on Fourier's Theorem and Harmonic Analysis for Physicists and Engineers. By Albert Eagle, B.Sc., A.R.C.Sc., Lecturer in Mathematics in the Victoria University of Manchester. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. xiv + 178.) Price 9*s*. net.

The Dynamical Theory of Sound. By Horace Lamb, Sc.D., LL.D., F.R.S., Honorary Fellow of Trinity College and Rayleigh Lecturer in Mathematics in the University of Cambridge; Formerly Professor of Mathematics in the Victoria University of Manchester. Second Edition. London: Edward Arnold & Co., 1925. (Pp. viii + 307.) Price 18*s*. net.

Calcul des Probabilités. Par Paul Lévy. Professeur à l'École Polytechnique Paris: Gauthier-Villars et Cie. 55 Quai des Grands-Augustins. 1925. (Pp. viii + 350.) Price 40 frs.

Tables and Charts giving Values of X^n. For the Use of Engineers and others. By A. D. Browne, M.A., Assoc. M.Inst. C.E. Cambridge: W. Heffer & Sons, 1925. (Pp. 10.) Price 1*s*. 6*d*. net.

The Mathematical Theory of Electricity and Magnetism. By J. H. Jeans, D.Sc., LL.D., F.R.S. Fifth Edition. Cambridge: at the University Press, 1925. (Pp. viii + 652.) Price 21*s*. net.

The Geometry of Réné Descartes. Translated from the French and Latin by David Eugène Smith and Marcia L. Latham. With a Facsimile of the First Edition, 1637. London & Chicago: The Open Court Publishing Company, 1625. (Pp. 245.) Price 17*s*. 6*d*. net.

Electrical Precipitation. A Lecture delivered before the Institute of Physics, by Sir Oliver Lodge, D.Sc., F.R.S. Physics in Industry. Volume III. London: Oxford University Press, 1925. (Pp. 40 with 5 plates.) Price 2*s*. 6*d*. net.

General Physics and its Application to Industry and to Everyday Life. By Ervin S. Ferry, Professor of Physics in Purdue University. Second Edition, revised. New York: John Wiley & Sons; London: Chapman & Hall, 1925. (Pp. xix + 807.) Price 20*s*. net.

Photo-Electricity. The Liberation of Electrons by Light, with Chapters on Fluorescence and Phosphoresence, Photo-Chemical Actions and Photography. By H. Stanley Allen, M.A., D.Sc., F.Inst.P., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews. Second Edition. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. xi + 320.) Price 18*s*. net.

An Introduction to Physical Science. By Ivor B. Hart. Oxford: at the Clarendon Press, 1925. (Pp. xii + 306, with 199 illustrations.) Price 4*s*. net.

The A.B.C. of Relativity. By Bertrand Russell, F.R.S. London: Kegan Paul, Trench, Trübner & Co., 1925. (Pp. iv + 231.) Price 4*s*. 6*d*. net.

The National Physical Laboratory. Collected Researches. Vol. xviii, 1924. London: published by His Majesty's Stationery Office, 1925. (Pp. iv + 455.) Price 17*s*. 6*d*. net.

Exercises in Practical Physics. By Sir Arthur Schuster, Ph.D., Sc.D., F.R.S., Honorary Professor of Physics in the University of Manchester, and Charles H. Lees, D.Sc., F.R.S., Professor of Physics in the University of London (East London College). Fifth Edition, revised. Cambridge: at the University Press, 1925. (Pp. ix + 373.) Price 12*s*. 6*d*. net.

Le Radium. Découverte de la Radioactivité et du Radium Origine de l'Énergie. Radioactive le Radium dans la Nature ses Emplois Usuels. Par F. Honoré. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1926. (Pp. 145.) Price 18 frs. net.

The Science of Soils and Manures. By J. Alan Murray, B.Sc., Lecturer in Agricultural Chemistry at University College, Reading. Third Edition, revised and enlarged. London: Constable & Company, 10 Orange St., Leicester Square, W.C.2, 1925. (Pp. xiv + 298, with 45 figures.) Price 12*s*. 6*d*. net.

Principles and Practice of Industrial Distillation. By E. Hausbrand. Translated from the Fourth, New, and Enlarged German Edition by E. Howard Tripp, Ph.D. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1925. (Pp. xx + 300, with 21 figures, 65 tables, and 16 charts.) Price 21*s*. net.

Volumetric Analysis. With a Chapter on Simple Gravimetric Determinations. By A. J. Berry, M.A., Fellow of Downing College and University Demonstrator of Chemistry, Cambridge. Third Edition. Cambridge: at the University Press, 1925. (Pp. v + 151.) Price 9*s*. net.

The Alkali Industry. By J. R. Partington, D.Sc., M.B.E., Professor of Chemistry, East London College, University of London. Second Edition. London: Baillière, Tindall & Cox, 8 Henrietta Street, Covent Garden, 1925. (Pp. xii + 344, with 84 figures in the text.) Price 12*s*. 6*d*. net.

Elementary Qualitative and Volumetric Analysis. By F. H. Campbell, D.Sc., F.A.C.I., Risdon Grimwade Tutor in Chemistry, Trinity College; Tutor in Chemistry, Ormond College. The University of Melbourne. Melbourne: MacMillan & Co., in association with Melbourne University Press, 1925. (Pp. iv + 99.) Price 6*s*. 6*d*. net.

Introduction à L'Étude des Colloïdes État Colloidal et ses Applications. Paris: Gauthier-Villars et Cie. 55 Quai des Grands-Augustins, 1926. (Pp. 220.) Price 16 frs. net.

Fundamentals of Physical Chemistry. For Students of Chemistry and Related Sciences. By Dr. Arnold Eucken. Translated and Adapted from the Second German Edition by Eric R. Jette, Ph.D., and Victor K. Lamer, Ph.D. London: McGraw-Hill Publishing Co., 8 Bouverie St., E.C.4. (Pp. xxiii + 699.) Price 27*s*. 6*d*. net.

Physiological and Clinical Chemistry. By William A. Pearson, Ph.C., Ph.D., M.D., and Joseph S. Hepburn, A.M., B.S., in Chem., M.S., Ph.D., Philadelphia and New York: Lea & Fibeger, 1925. (Pp. xvi + 306.) Price $4.

Textbook of Palæontology. By Karl A. von Zittell, late Professor of Geology and Palæontology in the University of Munich. Vol. iii, Mammalia. Edited by Max Schloesser, Ph.D., Curator of the Geological Museum at Munich, Translated under the direction of Charles R. Eastman, Ph.D. By Lucy P. Bush and Marguerite L. Engler. Translation revised, with Additions by Sir Arthur Smith Woodward, F.R.S. London: Macmillan & Co., St. Martins Street. (Pp. viii + 316, with 378 illustrations.) Price 25*s.* net.

The Surface History of the Earth. By John Joly, Sc.D., F.R.S., Fellow of Trinity College, Dublin. Oxford; at the Clarendon Press, 1925. (Pp. 192, with 11 figures and 13 plates.) Price 8*s.* 6*d.* net.

Monocotyledons. A Morphological Study. By Agnes Arber, M.A., D.Sc. Sometime Fellow of Newnham College, Cambridge. Cambridge: at the University Press, 1925. (Pp. xv + 258, with 160 figures.) Price 21*s.* net.

An Introduction to Plant Anatomy. By Arthur J. Eames, Professor of Botany, Cornell University, and Lawrence H. MacDaniels. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4, 1925. (Pp. xiv + 364, with 146 figures.) Price 17*s.* 6*d.* net.

Principles of Genetics. An Elementary Text, with Problems. By Edmund Sinnott, Professor of Botany and Genetics, Connecticut Agricultural College, and L. C. Lunn. Geneticist, Connecticut Agricultural Experimental Station. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4, 1925. (Pp. xviii + 431.) Price 17*s.* 6*d.* net.

Photosynthesis. The Assimilation of Carbon by Green Plants. By Walter Stiles, Sc.L., Professor of Botany in University College, Reading. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. vii + 268.) Price 16*s.* net.

Soil Characteristics. A Field and Laboratory Guide. By Paul Emerson, Ph.D., Associate Professor of Soils, Iowa State College. London: McGraw-Hill Publishing Co., 8 Bouverie Street, E.C.4, 1925. (Pp. x + 222.) Price 12*s.* 6*d.* net.

General Zoology. By H. L. Wieman, Professor of Zoology, University of Cincinnati. London: McGraw-Hill Publishing Co., 8 Bouverie Street, E.C.4, 1925. (Pp. ix + 311.) Price 15*s.* net.

A List of British Aphides. Including Notes on their Synonymy, their Recorded Distribution and Food Plants in Britain, and a Food-Plant Index.) By J. Davidson, D.Sc., F.L.S., Rothamsted Experimental Station, Harpenden. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. xi + 176.) Price 17*s.* 6*d.* net.

The Ascent of Man by Means of Natural Selection. By Alfred Machin. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. xix + 325.) Price 7*s.* 6*d.* net.

Aphrodite Aculeata. By Mahalah G. C. Fordham, M.Sc., Lecturer in Zoology, University of Liverpool. Liverpool Marine Biology Committee. Memoirs on Typical British Marine Plants and Animals. Edited by W. A. Herdman, G.B.E., F.L.S., and James Johnstone, D.Sc. No. XXVII. Liverpool: at the University Press; London: Hodder & Stoughton, 1925. (Pp. viii + 96, with 10 plates.) Price 5*s.* net.

The Dinoflagellates of Northern Seas. By Marie V. Lebour, D.Sc., F.Z.S., Naturalist at the Laboratory of the Marine Biological Association of the United Kingdom, Plymouth. Plymouth: published by the Marine Biological Association of the United Kingdom, 1925. (Pp. vii + 250, with 34 plates.) Price 12*s.* 6*d.*

British Mosquitoes and their Control. By F. W. Edwards. Assistant in the Department of Entomology, British Museum (Natural History), and S. P. James, M.D., Lt.-Col. I.M.S., Medical Officer, Ministry of Health. London: printed by Order of the Trustees of the British Museum, 1925. Pp. Economic Series No. 4*a.* (Pp. 27.) Price 6*d.*

Food and Health. By R. H. A. Plimmer, D.Sc., Professor of Chemistry in the University of London at St. Thomas's Hospital Medical School, and Violet C. Plimmer. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. 64.) Price, paper cover, 2*s.*; cloth 3*s.* 6*d.* Food Chart, 3*d.*

The Extra Pharmacopœia of Martindale and Westcott. Revised by W. Harrison Martindale, Ph.D., Ph.Ch., F.C.S., and W. Wynn Westcott, M.B., D.P.H. Eighteenth Edition. Vol. ii. London: H. K. Lewis & Co., 1925. (Pp. xlii + 728.) Price 20*s.* net.

Bacteriology. A Text Book in Fundamentals. By Stanley Thomas, M.S., M.A., Associate Professor of Bacteriology, Lehigh University. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4, 1925. (Pp. xiii + 201.) Price 12*s.* 6*d.* net.

A General Consideration of Snake Poisoning and Observations on Neotropical Pit-Vipers. By Afranio do Ameral, of the Serum-Therapeutic Institute, Butantan, Sao Paulo, Brazil, and of the Museu Paulista. Cambridge: U.S.A. Harvard University Press, 1925. (Pp. 64, with 16 plates.) Price 10*s.* 6*d.* net.

A Monograph on the Tetraphyllidea, with Notes on Related Cestodes. By T. Southwell, Ph.D., M.Sc., A.R.C.Sc., Lecturer in Helminthology, School of Tropical Medicine, Liverpool, late Director of Fisheries to the Governments of Bengal and Bihar and Orissa; Scientific Adviser and Inspector of Pearl Banks to the Ceylon Company of Pearl Fishers, and Honorary Assistant Zoological Survey of India, with a Foreword by Sir Arthur Shipley, G.B.E., F.R.S. Liverpool School of Tropical Medicine Memoir, No. 2. Liverpool: at the University Press; London: Hodder & Stoughton, 1925. (Pp. xv + 368, with 244 text figures.) Price 20*s.* net.

The Pathology of Tumours. By E. H. Kettle, M.D., B.S. London. Second Edition. London: H. K. Lewis & Co., 1925. (Pp. viii + 284, with 159 illustrations.) Price 12*s.* 6*d.* net.

Hexamines and Mucoproteins. By P. A. Levene, The Rockefeller Institute for Medical Research, New York. London: Longmans, Green & Co., 39 Paternoster Row, 1925. (Pp. x + 163.) Price 10*s.* 6*d.* net.

Ultra-Violet Radiation and Actinotherapy. By Eleanor H. Russell, M.D., B.S., Dunelm, and W. Kerr Russell, M.D., B.S., Dunelm. With Forewords by Sir Oliver Lodge, F.R.S., D.Sc., LL.D., and Sydney Walton, C.B.E., M.A., B.Litt. Edinburgh: E. & S. Livingstone, 16 Teviot Place, 1925. (Pp. iv + 262.) Price 10*s.* 6*d.* net.

The House of Health. What the Modern Dwelling Needs to Be. By Sir John Robertson, C.M.G., O.B.E., M.D., B.Sc. London: Faber & Gwyer, 1925. (Pp. 192.) Price 2*s.* 6*d.* net.

Nursing in the Home. Including First Aid in Common Emergencies. By Stella Churchill, M.R.C.S., L.R.C.P., D.P.H. London: Faber & Gwyer, 1925. (Pp. 197.) Price 2*s.* 6*d.* net.

The Fight Against Infection. By G. E. F. Stammers, O.B.E. With a Preface by Dr. Andrew Balfour, C.B., C.M.G. London: Faber & Gwyer, 1925. (Pp. vi + 214, with 24 illustrations.) Price 2*s.* 6*d.* net.

Bainbridge and Menzies' Essentials of Physiology. Fifth Edition, edited and revised by C. Lovatt Evans, D.Sc., M.R.C.S., L.R.C.P., F.R.S. Professor of Physiology, University of London, at St. Bartholomew's Medical College. London: Longmans, Green & Co., 39 Paternoster Row, E.C.4, 1925. (Pp. viii + 508, with 197 figures.) Price 14*s.* net.

Notes on Medical Case-taking and the Examination of Patients. By G. S. Haynes, M.D., M.R.C.P., Assistant Physician of Addenbrooke's Hospital. Cambridge: W. Heffer & Sons, 1925. (Pp. viii + 57.) Price 3*s.* net.

Strength of Materials. By Alfred P. Poorman, A.B., C.E., Professor of Applied Mechanics, Purdue University. London: McGraw-Hill Publishing Co., 8 Bouverie Street, E.C.4, 1925. (Pp. xi + 313.) Price 15*s.* net.

Sampling and Testing of Highway Materials. By W. H. Barton, Jr., M.S., C.E., and Louise H. Doane, M.S., B.S., in C.E. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4, 1925. (Pp. ix + 311.) Price 17*s.* 6*d.* net.

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The Theory of Measurements. By Lucius Tuttle, M.A., M.D., and John Satterly, M.A., D.Sc., A.R.C.S., F.R.S.L., F.R.S.C., Professor of Physics, University of Toronto. London: Longmans, Green & Co., 1925. (Pp. xi + 333). Price 12*s.* 6*d.* net.

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American Petroleum Supply and Demands. A Report to the Board of Directors of the American Institute by a Committee of Eleven Members of the Board. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4, 1924. (Pp. xii + 269.) Price 15*s.* net.

Coils and Magnet Wire. By Charles R. Underhill. London: McGraw-Hill Publishing Co., 6 Bouverie Street, E.C.4, 1925. (Pp. xi + 494.) Price 20*s.* net.

The Maori as He Was. A Brief Account of Maori Life as it was in Pre-European Days. By Elsdon Best. Wellington, New Zealand: Dominion Museum, 1924. (Pp. xv + 280, with 130 figures.)

A Brief Outline of the History of Science. By J. G. F. Druce, M.Sc., R.Nat.Dr. (Prague), F.I.C., Fellow of the Chemical Society. London: The Chemical News Ltd., Merton House, Salisbury Square, E.C., 1925. (Pp. 151.) Price 5*s.* net.

Essays By Divers Hands. Being the Transactions of the Royal Society of Literature of the United Kingdom. New Series, vol. v, Edited by John Drinkwater. London: Oxford University Press, 1952. (Pp. viii + 138.)

Teaching Science in the Schools. By Elliot Rowland Downing, the School of Education, University of Chicago. Chicago, Illinois: The University of Chicago Press. (Pp. xiii + 185, with 12 illustrations.) Price $2.

Art and the Unconscious. A Psychological Approach to a Problem of Philosophy. By John M. Thorburn, M.A., B.Sc. London: Kegan Paul, Trench, Trübner & Co., 68 Carter Lane, E.C., 1925. (Pp. xii + 242.) Price 10*s.* 6*d.* net.

Cawthron Lectures. Volume ii. The Cawthron Institute, Nelson, New Zealand. No. 1. The Geology of Nelson. By Dr. P. Marshall, No. 2. The Coming of the Maori. By Te Rangi Hiroa. Nelson, New Zealand: R. W. Stiles & Co., 1925. (Pp. 56, with illustrations.)

Spitsbergen Papers. Scientific Results of the First Oxford University Expedition to Spitsbergen (1921). London: Oxford University Press, 1925. Price 30*s.* net.

Science and Scientists in the Nineteenth Century. By the Rev. Robert H. Murray, Litt.D. With an Introduction by Sir Oliver Lodge, F.R.S., D.Sc. London: The Sheldon Press, Northumberland Avenue, W.C.; New York and Toronto: The Macmillan Co. (Pp. xvii + 450.) Price 12*s.* 6*d.* net.

Excavations in Malta. By M. A. Murray, F.S.A.Scot, Fellow of University College, London; Assistant-Professor of Egyptology in the University of London. With a Chapter by G. Caton Thompson. Part II. Percy Staden Memorial Fund Expedition. London: B. Quaritch, 11 Grafton Street, New Bond Street, 1925. (Pp. iv + 43, with 33 plates.) Price 7*s.* 6*d.* net.

The Personal Equation. By Louis Berman, M.D. London: George Allen & Unwin, 40 Museum Street, W.C.1. (Pp. xiii + 303, with 8 plates.) Price 8*s.* 6*d* net.

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The Scientific Study of Human Society. By Franklin Henry Giddings, Ph.D., LL.D., Professor of Sociology and the History of Civilisation in Columbia University. North Carolina: University Press, Chapel Hill; London: Oxford University Press, 1924. (Pp. vii + 247.) Price 9*s.* net.

The Relation Between Science and Theology. How to Think about it. By C. Stuart Gager. London and Chicago: The Open Court Publishing Co., 1925. (Pp. 87.) Price $1.

Mind and Matter. The Philosophical Introduction to Modern Science. By G. E. M. Joad. London: Nisbet & Co., 22 Berners Street, W.1. (Pp. vi + 170.) Price 4*s.* 6*d.* net.

The Northern Tribes of Nigeria. An Ethnographic Account of the Northern Provinces of Nigeria, together with a Report on the 1921 Decennial Census. By C. K. Meek, M.A., F.R.C.S., F.R.A.I. Volume i. London: Oxford University Press, 1925. (Pp., vol. i, xvii + 312, with 90 illustrations; vol. ii, viii + 277, with 25 illustrations.) Price 36*s.* net.

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Les Fondéments Biologiques de la Psychologie. Par Jean Lhermitte. Paris: Gauthier-Villars et Cie. 55 Quai des Grands-Augustins. (Pp. 241.) Price 14 frs. net.

Mathematics of Life Insurance. By L. Wayland Dowling, Ph.D., Associate Professor of Mathematics, University of Wisconsin. London: McGraw-Hill Publishing Co., 8 Bouverie Street, E.C.4. (Pp. x + 121.) Price 8*s*. 9*d*. net.

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Gems and Gem Materials. By Edward Henry Krais, Ph.D., Sc.D., and Edward Fuller Holden, Ph.D. London: McGraw-Hill Publishing Co., 8 Bouverie Street, E.C.4, 1925. (Pp. vii + 222.) Price 15*s*. net.

Esthétique. Par Pierre Guastalla, Preface de M. Charles Lalo. Paris: Librairie Philosophique J. Vrin, 6 Place de la Sorbonne, 1925. (Pp. xvi + 179.) Price 6 frs. net.

ERRATA

Owing to an unfortunate mistake, an uncorrected proof of Recent Advances in Astronomy was published in the last issue. The important errors were as follows:

Boss is misspelt *Bors* throughout.
Page 196, line 18, for *course* read *cosine.*
,, 196 ,, 28, for *rim* read *sine.*
,, 197 ,, 43, for *not* read *now.*
,, 198 ,, 35, for *right* read *sight.*
,, 200 ,, 37, for $+ 0''\cdot18 + 0''\cdot04$ read $+ 0''\cdot18 \pm 0''\cdot04$.
,, 201 ,, 5, for $\cos c$ read $\cos \delta$.
,, 201 ,, 5, for *record* read *second.*

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SCIENCE PROGRESS

RECENT ADVANCES IN SCIENCE

ASTRONOMY. By W. M. H. Greaves, M.A., Royal Observatory, Greenwich.

The Relativity Displacement of Spectral Lines in the Companion of Sirius.—In a previous article an account was given of Eddington's work on the relation between stellar masses and luminosities. From theoretical considerations Eddington deduced a functional relation between the mass of a star and its bolometric absolute magnitude after a small temperature correction had been applied to the latter. This relation was in point of fact found to be satisfied by stars for which the requisite data were available—a fact which was rather surprising as the theoretical reasoning which led to Eddington's relation assumed the law of a perfect gas to hold for the stars, whereas some of the actual stars for which the deduced relation was found to hold good were known to be " dwarf stars " with densities which are in some cases greater than that of water. Eddington explains this by pointing out that the departure from the law for a perfect gas is a consequence of the finite size of the atoms, whose effective diameters may be taken to be the diameters of the outermost electron orbits. Now in the case of stellar material at high temperature, the atoms will be ionised and stripped of most of their electrons. Consequently, the departure from the law of a perfect gas will set in at a much higher density than is the case in the laboratory, and so it is not so very surprising to find stars obeying a law which depends for its validity on the gas law being satisfied.

There was, however, one outstanding exception to Eddington's theoretical relation, namely, the companion to Sirius. This star is an early type of star of very low intrinsic brightness, and is known as a " white dwarf." It does not satisfy the theoretical relation in question, but Eddington suggested that this was due to the fact that its density was so high that the gas law was not satisfied in spite of the high ionisation. In fact, taking determined values of its parallax, mass, and apparent magnitude, and assuming a surface temperature of

8,000° corresponding to spectral type F0, the density comes out to be 53,000 times that of water. Eddington pointed out that such a star should show an Einstein displacement of its spectral lines of about 20 km. per sec.

An account of the attempt recently made at Mount Wilson to investigate any possible such Einstein shift is given by W. S. Adams, in the *Proceedings of the National Academy of Sciences*, vol. xi, pp. 382–7, July 1925. The difficulties of observation are very great. The angular separation between Sirius and its companion is 10″, and Sirius is 10,000 times as bright, with the consequence that the scattered light of Sirius produces a spectrum which is superposed on that of its much fainter companion. However, it was found possible to obtain spectrograms with the Mount Wilson 100-inch reflector, using a single prism spectrograph with an 18-inch camera. The average exposure time was 40 minutes.

The companion is of a later spectral type than Sirius, and consequently the distribution of energy in the continuous spectrum is different for the two stars, the red light being stronger for the companion. This was a very fortunate circumstance, as it enabled the observers to obtain the spectrum of the companion nearly free from the spectrum of Sirius towards the red end of the spectrum, whereas there was pronounced superposition in the blue. It was considered that the line $H\beta$ was practically free from superposition, and that no correction need be applied to measurements of line-displacement derived from this line. The relative displacements of this line in the spectra of the companion and of Sirius itself were measured from the spectrograms, and after correcting for the known relative radial velocity a displacement of 24 km/sec was obtained. Measures were also made for H_γ and for several metallic lines, but these measures had to be corrected for the effect of superposition of the scattered light from Sirius on to the spectrum of the companion. The final mean result for the Einstein shift was 21 km/sec in close agreement with Eddington's prediction.

The closeness of the agreement is in fact rather of the nature of a fluke, as the difficulties of measurement are great. Eight determinations were made from the $H\beta$ line and the individual results are 29, 21, 22, 15, 29, 25, 26, and 23 kilometres per second, with a weighted mean of 24 km/sec. In the cases of H_γ and of the metallic lines, the ranges are much greater.

When the discovery of the Einstein shift in the lines of the solar spectrum was announced over a year ago by Evershed and St. John, it was thought that the last word had been probably said as regards experimental verifications of Einstein's theory. The theory had satisfied the three crucial tests, the motion of the perihelion of Mercury, the gravitational bending of light, and the displacement of the lines in the solar spectrum. It seemed as if no other test could be applied, and it is very satisfactory to obtain results which, although admittedly difficult to obtain, and subject to considerable accidental error of measurement, still give evidence confirmatory both of Einstein's theory and of the remarkable density predicted by Eddington for the companion to Sirius.

The Solar Parallax from Observations of Occultations at the Cape Observatory.—It is well known that the motion of the moon involves terms which depend on the value of the solar parallax, and that consequently observations of the moon's position provide a means of determining this important constant. Unfortunately, the solar parallax as determined in this way from meridian observations of the moon, is liable to systematic error. This arises from the fact that when the parallactic inequality (that is, those terms in the expressions for the moon's position which involve the solar parallax) is positive only one limb of the moon can be observed, and the other limb when the inequality is negative. The solar parallax will therefore be affected by any error in the adopted value of the moon's semi-diameter, a quantity which it is very difficult to determine from meridian observations on account of the effects of irradiation. Observations of the occultations of stars by the moon provide an alternative method which seems to be free from this defect, and in the *Monthly Notices of the Royal Astronomical Society* for November 1924, Dr. Spencer Jones has discussed the occultations observed at the Cape Observatory for the period of 1835 to 1922. For the whole of this period the observations have been compared with predictions based on Hansen's tables of the moon. From 1923 onwards Brown's tables have been used as the basis of comparison.

Each observation of an occultation yields an equation involving the errors of the moon's position and semi-diameter as computed from the tables. The equations were transformed, the new unknowns being the errors of the elements of the orbit, of the coefficient of the principal term in the parallactic inequality, and of the tabular semi-diameter. Corrections have been applied which take into account terms omitted by Hansen's theory. The resulting equations were solved by least squares and from the resulting value of the coefficient of the principal term in the parallactic inequality the value of the solar parallax was determined. Dr. Spencer Jones's final result for the solar parallax is

$$8''\cdot805 \pm 0.005.$$

This may be compared with the value derived by Hinks from the observations of Eros. Hinks's value was

$$8\cdot806 \pm 0''\cdot004.$$

The agreement of these two determinations is highly satisfactory.

PHYSICS. By L. F. Bates, B.Sc., Ph.D., F.Inst.P., University College, London.

Atomic and Ionic Forces.—We have long ceased to regard the representation of an atom by a rigid sphere as adequate, for the values of the diameter of an atom obtained by different methods are so very diverse. For example, the following values of the diameter of an atom of argon are taken from Herzfeld's *Kinetische Theorie der Wärme*, p. 420. From viscosity measurements the diameter is found to be 2·97 Å; from the Van der Waals constant, *b*, it is found to be 3·00, 2·92 or 2·42 Å according as *b* is calculated from the critical pressure and temperature, from the critical volume or from a discussion of the isotherms at higher temperatures (*Zwicky*, *Phys. Zeit.*, vol. 22, p. 449, 1921) respectively. From the volume occupied by liquid argon the diameter deduced is 4·04 Å, whilst from measurements on the solid state the value 3·84 Å is found. Moreover, it is difficult to justify such a conception side by side with the Rutherford-Bohr theory of atomic structure. In fact, the only reason for the long popularity enjoyed by the spherical atom is its simplicity alone, for it involves only one unknown quantity, namely, its diameter.

Now most chemical and physical properties of matter depend entirely on the forces between atoms, and it therefore follows that the most fundamental information which can be obtained from many physical data is that concerning the nature of interatomic forces, and an interesting systematic attempt to use the experimental data at our disposal for such a purpose has recently been made by Lennard-Jones. In a series of papers he replaces the old rigid sphere model by an inverse power law model, which is much more general, and which is shown to include the former model as a special case. In the first of this series of papers (*Proc. Roy. Soc.*, vol. 106, p. 441, 1924) the molecules are supposed to repel according to an inverse n^{th} power law, and to attract according to an inverse 3^{rd} power law; no attempt is made to justify the specified attractive field, it merely happens that it lends itself to mathematical treatment. It is found that with this model the viscosity of a gas varies, as a first approximation, according to the law $T/(T^{(n+5)/2(n+1)} + ST^{-1})$, where S is a quantity independent of the temperature T. When n tends to infinity the usual Sutherland formula is obtained, and when S is zero we obtain the usual result for molecules which repel according to an inverse n^{th} power law without attraction. Now from the above formula, a detailed consideration of the constant S leads to the assumption of a formula of similar type for the variation of the coefficient of viscosity when the general law of force is $\lambda_n r^{-n} - \lambda_m r^{-m}$, *i.e.* when the attractive force obeys an inverse m^{th} power law. However, the expression given above satisfies the observed variation of the viscosity of argon with temperature over the range − 180° C. to 180° C. with no greater deviation than 0·6 per cent., but agreement between experiment and theory can be obtained with more than one molecular model, e.g., n may have any value from 15 to 25, so that viscosity results by themselves do not lead to a unique determination of molecular fields. Therefore, in a second paper (*Proc. Roy. Soc.*, vol. 106, p. 463, 1924) experimental data concerning the equation of state of a gas are examined to determine whether, in conjunction with the results based on considerations of viscosity, they will definitely fix the molecular field. Kamerlingh Onnes (*Comm. Phys. Lab. of Leiden*, No. 71) expresses his experimental results for certain gases in the form of an empirical equation of state, $p_v = A + B/_v + C/_{v^2} + D/_{v^3} \ldots$, where B is known as the second virial coefficient. Lennard-Jones obtains a theoretical expression for B in terms of the temperature on the basis of the new atomic model, and by graphical methods this model is tested against the results of Kamerlingh Onnes. It is found again that more than one kind of repulsive field will explain the facts, and the constant of the repulsive force is in all cases greater than that deduced from viscosity measurements. In an appendix to this paper, the more recent results of Holborn and Otto (*Zeit. für Phys.*, vol. 23, p. 77, 1924) on the isotherms of gases from 0° to 400° C. are considered, and the graphs show that good agreement is found for all models with n greater than 9, and with the same kind of attractive field.

Now, although it is not possible to deduce conclusive information about molecular fields from the above two sets of measurements alone, it is shown in a third paper (*Proc. Roy. Soc.*, vol. 106, p. 709, 1924) that some definite conclusions may be obtained by making use of X-ray measurements of crystals. In fact, in this paper, an attempt is made to bring the properties of a gas into line with the properties of a crystal. It is shown possible, with a series of inverse power models described above, to make theoretical calculations of the interatomic distances in crystalline argon, which has recently been produced and subjected to X-ray measurement (Simon u. Simson, *Die Naturwiss.*, vol. 11, p. 1015, 1923; *Zeit. für Phys.*, vol. 21, p. 168, 1924, and vol. 25, p. 160, 1924), and hence, for the first time we have information derived from kinetic theory applied to explain interatomic distances in crystals. The attempts to determine atomic diameters from crystal measurements made by W. L. Bragg and Wasastjerna are based on the conception of rigid spheres, and lead to values which differ from those obtained by other methods; *e.g.* they are often considerably less than those obtained from viscosity data. The conception of a repulsive field according to an inverse 10th power of the distance in conjunction with forces due to electrostatic charges, is used by Born and Landé (*Ver. d. Deut. Phys. Ges.*, vol. 20, p. 210, 1918) to explain the experimental results of the compressibility of crystals, but these experiments on compressibility are so difficult that it is hard to decide how much reliance may be placed on the information thus obtained. Now, argon forms crystals of the face-centred cubic type and the observed value of the interatomic distance is 3·84 Å. Taking the force between two argon atoms to be represented by $\lambda_n r^{-n} - \lambda_m r^{-m}$, Lennard-Jones obtains an expression for the distance between atomic centres in simple cubic and face-centred cubic crystals, where λ_n and λ_m may be obtained from the results of Holborn and Otto, as described in the second paper of this series. He thus finds that both the results of Holborn and Otto and the observed interatomic distance in crystalline argon may be explained on the supposition that the force of repulsion between two argon atoms obeys an inverse 15th power law, whilst the force of attraction obeys an inverse 5th power law; it must be mentioned that the results of Holborn and Otto appear to meet the case better than those of Kamerlingh Onnes. Incidentally, it is shown in this instance that the face-centred cubic form possesses less potential energy than the simple cubic crystal, although the individual atoms are farther apart. It is also pointed out that a KCl crystal may be considered as a series of argon atoms to which are added, alternately, positive and negative electrostatic charges; for X-ray analysis shows that a KCl crystal consists of two interpenetrating face-centred cubics and may therefore be regarded as of the simple cubic type, the corners of the cube being occupied by positive and negative ions, since it may reasonably be assumed that the valency electron of the K atom is absorbed into the outer structure of the Cl atom in such manner that both these ions possess the same outer shell of electrons as an atom of argon. Similarly, a crystal of CaS may be regarded as a collection of argon atoms to which are added, alternately, double positive and negative electrostatic charges, and which are arranged in a simple cubic lattice. The distances between these atoms are calculated for the model

$\lambda_n r^{-n} - \lambda_m r^{-m}$, where $n = 15$, $m = 5$, $\lambda_n = 1{\cdot}721 \times 10^{-117}$ and $\lambda_m = 1{\cdot}107 \times 10^{-48}$. The observed and calculated interatomic distances for crystalline argon are 3·84 and 3·86 Å, for KCl 3·13 and 3·08 Å, and for CaS they are 2·77 and 2·79 Å respectively. In a fourth paper (*Proc. Roy. Soc.*, vol. 107, p. 157, 1925) Lennard-Jones extends the methods of the previous papers to the atomic fields of helium and neon. An examination of the data for the second virial coefficient in the case of helium shows that the field of the helium atom may appropriately be represented by the superposition of inverse power law repulsive and attractive fields, of which the force constants may be calculated. The viscosity data for helium given by Kamerlingh Onnes and Weber (*Comm. Phys. Lab. Leiden*, No. 134B, p. 18, 1913) are also used to determine the value of the repulsive force constant, and the values of the atomic diameter obtained from the two sets of data are in remarkably good agreement; they are 3·105 Å and 3·128 Å respectively, for given values of n and m. The field of helium is found to be one of repulsion according to an inverse 14th power law together with a weak attraction according to an inverse 5th power law; as a matter of fact, the attractive field is so weak that from viscosity results alone it would appear that the field was purely repulsive, and the attractive force constant is only about 1/100th of that previously found for argon. The experimental data in the case of neon is much more meagre, for values given for the second virial coefficient at the same temperature differ by as much as 100 per cent., and experimental values for the viscosity are known for only two temperatures, so that measurements of the thermal conductivity are used to deduce the corresponding values of the viscosity, by means of a formula due to Chapman. In the manner described in the previous papers, X-ray measurements of the crystals NaF and MgO are used to determine the atomic field of neon, and it is concluded that neon repels according to an inverse 21st power law.

Lennard-Jones and P. A. Taylor (*Proc. Roy. Soc.*, vol. 109, p. 476, 1925) then elaborate and extend the work of the previous papers to take account of the recent work of Wasastjerna (*Soc. Scient. Fenn. Comm. Phys. Math.*, vol. 1, p. 38), who deduces the refractivities of a number of atoms and ions from the refractive indices of crystals and salts, and who further uses these refractivities to calculate the relative sizes of atoms and ions of similar atomic structure (*Wasastjerna*, *l.c.*, p. 37). The relative "sizes" obtained by Wasastjerna are presumed to refer to the average distances of the outer electron orbits from the nucleus, and hence, it is further assumed that they give the variations of the kinetic theory diameters, so that if one diameter is known (*e.g.* that of the pure gas), then the others may be calculated, and the authors give a table of values obtained by making use of the results of the previous papers. The idea of a diameter is then somewhat generalized in conformity with the mode of representing the field of an atom by an inverse power law force instead of a rigid sphere. The potential function for the given atom is plotted and the "diameters" considered by the authors are given by the intersections of an ordinate of value $3kT/2$ with the curves thus obtained for different values of n, and these "diameters" are assumed to be proportional to the scale of the outer orbits of the atom, so that the value of the "diameter" of an ion may be deduced from Wasastjerna's figures, and then the repulsive force constants of an ion may be calculated. For certain assumed power laws the repulsive force constants are known for atoms of neon and argon, so that the repulsive force constants for each of the eight ions O^{--}, F^{-}, Na^{+}, Mg^{++}, S^{--}, Cl^{-}, K^{+} and Ca^{++} are readily found for these particular cases. Theoretical calculations of interatomic distances in crystals taking the attraction between ions to be due to their electrostatic charges are then made, and the results are compared with those of experiment to decide which of the various models is most adequate to fit the facts. It is thus found that in crystals the repulsive forces of neon-like ions may be represented by an inverse 11th power law, whilst the argon-like ions may be represented by an inverse 9th power law. Crystals similar to NaCl are treated by considering the forces between an argon-like and a neon-like ion, it being assumed that the repulsive force between one of each kind of ion obeys an inverse 10th power law. In this way tables giving the force constants between any two of the monovalent ions F^{-}, Na^{+}, Cl^{-}, K^{+}, and between any two of the divalent ions O^{--}, Mg^{++}, S^{--}, and Ca^{++} are drawn up. The methods are further applied to predict the interatomic distances of $CaCl_2$ which have not yet been measured. Incidentally, the properties of crystalline argon are further discussed, for whilst it is shown in the third paper that there is a repulsive force obeying a 15th power law between argon atoms in the crystalline state, an inverse 9th power law appears to hold for argon-like cores, when we take into account the sizes of the ions, as, for example, in the case of K^{+} and Cl^{-}.

The most recent paper of this series (*Proc. Roy. Soc.*, vol. 109, p. 584, 1925) is the result of the application of the methods of the preceding papers to krypton-like and xenon-like ions, but in this case the fields of krypton and xenon are deduced from crystal data alone. Thus the only information necessary for krypton is the interatomic distances of Rb Br as well as the refractivities of Br$^-$, Kr, and Rb$^+$, and that for xenon is the compressibility of CsI, together with the refractivities of Cs$^+$, Xe and I$^-$. The net results of these papers are embodied in tables showing the laws of force and force constants between any two of the pure gas atoms Ne, A, Kr and Xe, and between any two of a series of neon-like, argon-like, krypton-like and xenon-like ions. With these force constants and repulsive power indices, calculations are made of the compressibilities, heat contents, etc., of 32 crystals and the results are shown to be in satisfactory agreement with experiment ; calculations are also made of a number of crystal constants not yet observed, and clearly many further interesting and important physical and thermochemical applications of the detailed knowledge of atomic and ionic forces, gained as a result of these researches, may be anticipated.

Recent Advances in Radioactivity.—It has long been known that the loss of charge of an enclosed electroscope could only be explained by the presence of a penetrating radiation in the atmosphere. Yet, until recently, no conclusive experiments decided the origin of this radiation, although the experiments of Hess and Kohlhörster indicated that this penetrating radiation did not proceed from the earth, but had its origin somewhere outside it. The experiments recently made by Millikan and his collaborators (*Nature*, December 5, 1925) are therefore of great interest. In the first place, experiments were made by Bowen and Millikan in which recording electroscopes were sent up in sounding balloons to heights as great as 15·6 km., and they confirmed the results of Hess and Kohlhörster that the penetrating radiation was greater at higher altitudes than at the surface of the earth. Secondly, experiments by Millikan and Otis indicated the existence of a small and very penetrating radiation of cosmic origin, and a quantity of soft γ-rays whose intensity appeared to increase with altitude. Finally, experiments made by Cameron and Millikan with electroscopes sunk in very deep snow-fed lakes at very high altitudes, proved conclusively the existence of a cosmic radiation which decreased in intensity down to depths of 45 ft. This meant that they were dealing with rays which could penetrate 6 ft. of lead before being completely absorbed. Moreover, the experiments also showed that these rays were not homogeneous. No change in the intensity of this radiation was found by day or night, so that it must traverse space in all directions. The softer radiation investigated was clearly produced, in accordance with the Compton effect, when the extremely hard cosmic radiation struck the earth, and the reason that this scattered radiation increases with altitude is simply explained by the fact that at higher altitudes there are correspondingly more hard rays to be transformed. Millikan suggested that this radiation resulted from nuclear transformations of some kind, but Jeans (*Nature*, December 12, 1925) has considered the possibility that it may arise from the annihilation of stellar matter, which would produce a wave-length of $1 \cdot 3 \times 10^{-13}$ cm., corresponding to the simultaneous destruction of one electron and one proton. Jeans also points out that now, in addition to visible radiation, we must consider space to be traversed by extremely hard γ-rays and extremely high velocity β-rays, and he states that these rays obviously explain the luminosity of such objects as the irregular nebulæ, and the negative charge of the earth.

Rutherford and Chadwick (*Phil. Mag.*, November 1925) have recently given an account of new scintillation experiments for the investigation of atomic nuclei and the law of force. Although from their previous experiments the inverse square law was known to hold for collisions between α particles and the nuclei of the heavier elements, it was also known to break down completely in the case of collisions with H nuclei, in which the closest distance of approach was of the order of 4×10^{-13} cm. The scattering of α particles by magnesium and aluminium was also studied by Bieler, and deviations from the inverse square law were accounted for by the superposition of an attraction obeying an inverse 4th power law. The experiments now described were devised to examine the validity of the inverse square law for the closest possible distance of approach for the heavier elements, and to determine the nature of the variation of the scattering with the velocity of the impacting α particle for the lighter elements. The examination of the scattering by uranium was of particular importance, for it would appear that an α ray from radium C, of range 7 cm., should penetrate deeply into the structure of the uranium nucleus, and therefore some radical departure from the usual laws of scattering would be expected. The scattering from a thin film of uranium, deposited on a plate of graphite by cathode sputtering, was examined at an angle of 135° and compared with that of gold under the same conditions, but no indication of any departure was found within the limits of experimental error. Incidentally, experiment showed that the gold nucleus behaved as a point charge and that the law of force is the inverse square law for distances up to $3 \cdot 2 \times 10^{-13}$ cm. from the nucleus. In the case of the scattering of the elements magnesium and aluminium, similar experiments showed definite departures from the usual laws of scattering, for the scattering of α particles of 6·7 cm. range was less than the theoretical value and decreased as the energy of the incident α particles was diminished, reaching a minimum for particles of range about 5 cm., and afterwards attaining the theoretical value for particles of small range. Check observations were provided by experiments on scattering at an angle of 90°. These scattering results may be explained, in general terms, by considering the aluminium nucleus to be a complex system consisting of a central core surrounded by a satellite arrangement of positive and negative charges. It is interesting that in the case of aluminium the minimum in the scattering curve occurs for about the same velocity of the α particle as that for which the liberation of protons from aluminium is first observed; this suggests that a proton is not liberated until the α particle actually penetrates the satellite system.

A series of short but important papers is published in the *Proceedings of the Cambridge Philosophical Society* for November 1925. In the first place D. H. Black examined the low energy β-rays from radium B + C and found definite evidence of a line spectrum which must be due to the ejection of electrons by $\sigma\lambda$, λ L X-rays from an atom of atomic number 83 acting on the M, N and O levels of the same atom. This β-ray spectrum was analyzed, and the results shown to give strong support to the hypothesis that electrons are ejected by γ-rays after the nuclear change in the atom has taken place, for at the moment of expulsion of the disintegration electron from radium B, the internal atomic structure of radium B corresponds to an atom of atomic number 82, and therefore these L X-rays must be generated by rays proceeding from the nucleus after the disintegration has occurred. The bearing of these results on the determination of the wave-lengths of γ-rays by Rutherford and Andrade is discussed by Rutherford and Wooster (*loc. cit.*), who made a new examination of the soft γ radiation in the natural spectrum of radium B to settle with certainty whether it should be ascribed to an element of atomic number 82 or 83. They used a method similar to that of Rutherford and Andrade with crystals of rock salt and calcite, and a radon tube as source. They found that the early measurements of the L spectrum were subject to some unknown source of error and the more recent evidence was clearly in favour of an atomic number 83. Additional evidence that γ-rays are emitted after the disintegration of the nucleus is given by Ellis and Wooster, who compared the natural β-ray spectrum of radium B with that excited in platinum. By taking photographs of these spectra on the same photographic plate, they measured the difference in energies of the K levels of the emitting substance and of platinum, and hence found the atomic number of the radioactive element emitting the γ-rays. The bearing of these results on the β-ray type of disintegration is discussed in a further paper by Ellis and Wooster (*loc. cit.*), and in dealing with the continuous β-ray spectrum they conclude that the disintegration electron is emitted from the nucleus with a varying velocity, but they advance no hypothesis to account for such an emission.

Lise Meitner, who first put forward the above view of γ-ray emission, deals in two recent papers (*Hahn u. Meitner, Zeit. für Phys.*, vol. 34, p. 795, 1925, and Meitner, *ibid.*, p. 807) with the β-ray spectrum of radioactinium and its disintegration products. Radioactinium is a substance which emits α-rays and its β-radiation must be regarded as secondary, *i.e.* it must arise by conversion of γ-rays from the nucleus in the atom itself. It is consequently of interest to examine the β-ray spectra of radioactinium, actinium X, and the active deposit when each of these substances is obtained separately and contains as little as possible of the others. Preparations of radioactinium, in a non-emanating state and containing only 0·5 per cent. of Actinium X, were obtained, and photographs of the β-ray spectra were taken with exposures of various durations. Now, photographs with exposures of less than 24 hours' duration should very approximately represent the β-ray spectrum emitted by radioactinium alone, and those with exposures of longer duration should exhibit lines corresponding to the spectra of the various disintegration products. As controls, spectra corresponding to actinium X of 98 per cent. purity, and to the active deposit alone, were examined. The photographs are very interesting, for certain lines enter into those obtained with the longer exposures much more intensely, others less intensely in comparison, and new lines appear, and hence the lines corresponding to the various products can be found. Forty-nine lines were thus measured in the β-ray spectrum of radioactinium, twenty-one in that of actinium X, and nine in that of the active deposit; but the last number refers only to the most intense lines of the active deposit. Thus radioactinium and actinium X must both possess a complicated γ-ray spectrum, although both emit α-rays. These experiments are particularly important because the nuclei of the parent atom and the disintegration atom differ by two units, and these substances are, therefore, more suitable for the experimental examination of the question of the origin of γ-rays than β-radiating substances. The results leave no doubt that γ-rays are converted in the electron levels of the disintegration atom, *i.e.* the γ-ray is emitted after the disintegration has taken place.

In view of the many theoretical discussions of the experiments of Bucherer on the variation of the mass of the electron with velocity, a description of some preliminary results obtained by R. A. Tricker (*Proc. Roy. Soc.*, vol. 109, p. 384, 1925) is of interest. As a ready-made source of β-rays of great homogeneity he used the lines emitted by radium B + C, whose velocities have been recorded with an accuracy of 1 in 500 by Ellis and Skinner. He sent the β-rays first through an accelerating and then a retarding electric field in a special focussing apparatus, and measured the traces formed on a photographic plate. The results obtained with rays of velocities up to 0·8 c. agree with the results of the theory of relativity, and the order of accuracy was the same as in Bucherer's experiments. However, by increasing the electric fields, future experiments will be carried out with greater accuracy.

GEOLOGY.

By G. W. TYRRELL, F.G.S., A.R.C.Sc., Ph.D., University, Glasgow.

Geophysics and Geochemistry.—Two books of extreme importance on the larger problems of the earth have recently appeared in this country. The first of these works, Dr. H. Jeffreys' *The Earth : Its Origin, History, and Physical Constitution* (Cambridge University Press, 1924, pp. 278), is written mainly from the cosmogonic and geophysical point of view. Prof. J. Joly's book on *The Surface History of the Earth*, however, deals with geological history as a consequence of the radioactivity of the rocks (*postea*).

A valuable feature of Dr. Jeffreys' book for geologists is its clear discussion of such terms as solid, liquid, stress, elasticity, set, rigidity, strength, plasticity, and viscosity, which are so frequently misused. It is, of course, impossible to deal with a work of this magnitude in a paragraph or two ; and all we can do (disregarding the important cosmogonic portion of the book) is to enumerate the topics which most directly concern the geologist, and in which valuable additions to, and clarifications of, knowledge have been made.

The principal geological topics discussed by Dr. Jeffreys are the physical constitution, age, and thermal history of the earth, the nature of isostasy, and the causes of mountain formation. We may quote part of the summary of the conclusions on the thermal history of the earth : " . . . There is good reason for suspecting that the rocks in continental regions at a depth of 16 kms. are typically basic. . . . Further, the cooling of the earth since solidification amounts, at a depth of some 300 kms., to between 200° and 300° C. ; at a depth of 700 kms. the cooling is as yet insignificant. Under the oceans the cooling must be somewhat greater at all depths. The physical significance of these results is that the physical state of the matter at great depths can scarcely have changed since solidification, and therefore it may be expected to show in some respects at least the usual properties of a liquid; namely, it should be capable of being deformed to any extent by a shearing stress, however small, provided this acted for a long enough time; and it should be devoid of rigidity, and therefore unable to transmit distortional waves."

A long critical review by T. C. Chamberlin, dealing chiefly with Jeffreys' cosmogonical ideas, has appeared (*Journ. Geol.*, **32**, 1924, pp. 696–716); to which Jeffreys has replied at length, affirming and amplifying his criticisms of Chamberlin and Moulton's planetesimal theory (*Amer. Journ. Sci.*, **9**, 1925, pp. 395–405).

A new book by Dr. B. Gutenberg (*Der Aufbau der Erde*, Berlin, 1925, pp. 168) presents a general survey of the condition of the interior of the earth as so far known from the results of modern geophysical and geochemical investigations. The topics treated are grouped under the headings of seismology, the figure of the earth, the internal distribution of density, chemical composition, and the cooling of the earth. A review by Dr. Jeffreys is to be found in *Nature*, January 16, 1926, p. 78.

A very suggestive paper on the geological effects of the condensation of the earth and the resulting acceleration of rotation, by the late Prof. J. Barrell, has appeared under the editorship of Dr. C. Longwell, one of Barrell's students (*Amer. Journ. Sci.*, **10**, 1925, pp. 408–32; 499–529; **11**, 1926, pp. 27–41). This work, dealing in Barrell's inimitable way with many of the earth problems treated by Dr. Jeffreys in *The Earth*, was initiated by the reading of T. C. Chamberlin's volume on *The Origin of the Earth* (1916), and was written in the same year. Its conclusions, as Dr. Longwell points out, would undoubtedly have been considerably modified if Barrell had had the opportunity of utilising the work of Jeffreys and Joly, especially in regard to the adequacy of the cooling hypothesis to account for the known shortening of the crust.

The paper is divided into three parts: 1, on internal stresses and changes of figure; 2, the spheres of the earth and their effects on the lithosphere; 3, on theoretical relations to joint systems. The geological conclusions are that: ". . . So far as stresses in the earth's body are concerned, those due to change of oblateness would appear to be wholly submerged beneath those due to change of volume. . . . On the other hand, it appears probable that planetary strains occur in the outermost shell of the crust, the zone of fracture, which may constitute one of the major factors in determining the nature of regional joint systems." Barrell gives reasons for the existence of a zone of burden or strength, the *achthosphere*, extending from 722 kms. to 1,600 kms. depth below the asthenosphere or zone of weakness, the function of which is to store up the stress produced by the progressive changes towards condensation in the inner earth. The akthosphere is thus supposed to exist between the asthenosphere, in which heat is generated, and a condensing core, the barysphere, in which heat is more probably absorbed.

Adherents of the doctrine of isostasy have shown a disposition to hold that the isostatic anomaly is due to irregularities near the surface of the earth. F. A. Melton, however (*Amer. Journ. Sci.*, **10**, 1925, pp. 166–74), puts forward considerations leading to the view that it may represent much greater irregularities in density within the outer 100 kms. or more of the earth, than has hitherto been thought.

Prof. R. A. Daly's recent work on " The Pleistocene Changes of Level " (*Amer. Journ. Sci.*, **10**, 1925, 281–313) is also largely concerned with isostasy. The world-wide changes of sea-level in the Pleistocene were effected by the withdrawal of water to form ice-caps and its restoration to the oceans, and by elastic and non-elastic reactions of the earth to loads of ice and water, both positive and negative. Long delays or lags in isostatic adjustment occurred in which the elastic distortion of the globe was an important factor.

Prof. Daly has imagined a " punching " hypothesis to account for the mode of displacement of the part of the crust immediately beneath an ice-cap. The failure of the earth sector is believed to take place by distributed vertical shearing instead of lateral outward flow near the surface. The stress differences and shears are thus carried downward to a depth at which the low strength of the material permits yielding to take place by horizontal flow. In this deep zone the flow continues until isostatic equilibrium is attained. Hence arises a broad basin of depression beneath an ice-sheet, and a relatively elevated tract outside it. With unloading, the glaciated area and the elevated rim are alike immediately uplifted by the elastic response of the crust ; and the difference in elevation persists until the rigidity has sufficiently decayed. Then comes the ultimate restoration of isostatic balance by a reversal of the punching process.

A study of the geotherms of the Lake Superior country by Prof. A. C. Lane (*Bull. Amer. Geol. Soc.*, **34**, 1923, pp. 703–20) shows that while the average temperature gradient is one degree F. per 105 feet, in depth the gradient is steeper, namely, 1° F. in 90 feet. This increase is ascribed to a warm wave which started at the surface 10,000 years ago, and is regarded as evidence of a milder climate between the Ice Age and the present time. Similar post-glacial heat-waves should be looked for in the temperature records of other deep wells and mines.

L. H. Adams (*Journ. Wash. Acad. Sci.*, **14**, 1924, pp. 459–72) has discussed the temperatures obtaining at moderate depths within the earth, by determining the initial temperature distribution when the earth began to cool as a solid body. The calculation extends to 300 kms. depth, and is based on an initial temperature distribution arising from the crystallisation of a primitive peridotite magma from the bottom upwards. It is notable that Adams thinks it probable, in opposition to recent ideas, that a large part of the upper 2,000 kms. is crystalline; although the material at greater depths may be in the glassy state.

The relation of the physical properties of natural glasses to their chemical composition is discussed by W. O. George (*Journ. Geol.*, **32**, 1924, pp. 353–72). The index of refraction and the specific gravity are closely related to the composition; but fusibility, colour, hardness, solubility, and magnetism are found to be unreliable indicators of the nature of the glass. Alkalic glasses seem to show higher indices of refraction than subalkalic glasses of the same density.

Prof. J. Joly has expanded his brilliant theory on the connection of radioactivity with the history of the earth's crust (see SCIENCE PROGRESS, January 1924, pp. 382–3) into a volume entitled, *The Surface-history of the Earth* (Oxford University Press, 1925, pp. 192), with which is incorporated a report of his lecture on the same subject to the Geological Society. This report forms a convenient summary of the book. As Joly's theory has already been outlined in these notes, and as Dr. A. Holmes has written an excellent review-summary (*Nature*, December 19, 1925, pp. 891–3), there is little need for further comment, except to agree with Holmes as to the fundamental importance of the book for the major problems of geology. The question of continental drift as urged by Taylor and Wegener appears, however, to be accorded much less notice in the book than in Joly's earlier papers.

The accumulation of new facts has shown that Dr. A. Holmes's illuminating theory of the connection of radioactivity with the thermal history of the earth breaks down in one vital point, namely, that of the origin of vulcanism; and he has therefore completely reconstructed the theory, and has linked it on to Joly's conceptions (*Geol. Mag.*, **62**, 1925, pp. 504–15; 529–44).

Joly's application of his theory to earth-history gives only three or four cycles of about 40 million years since the beginning of the Palæozoic, agreeing with his well-known determination of the age of the earth from the sodium content of the ocean. Holmes, however, points out that methods based on radioactivity give a figure of 600 million years for the same period; and, if this be accepted, many more than four cycles must have occurred. Perhaps the most fertile suggestion in his paper is that the more prominent diastrophic periods (which Joly takes as marking his cycles) are really due to the superimposed effects of the radioactive accumulation of heat in a peridotite stratum situated beneath the basaltic layer, the thermal oscillations of which provide the normal cycle. Owing to its smaller content of radium the peridotite stratum has undergone fewer cycles of fusion and solidification than the basaltic, but of much longer duration, so that its effects become prominent at the surface at long intervals, when it intensifies the effects due to the basaltic cycle.

The radioactive methods of determining the ages of rocks have been discussed in a popular manner by Prof. A. C. Lane in a paper on Laurentian Problems and Atomic Disintegration (*Trans. Canadian Inst. Min. and Met.*, **28**, 1925, pp. 1–25). He thinks there are reasonable prospects of determining the relative ages of different Pre-Cambrian granites in this manner, and thus helping to solve the intricate stratigraphical problems of the Canadian Shield.

L. H. Adams and E. D. Williamson (*Smithsonian Report for* 1923, 1925, pp. 241–60) have assembled the principal sources of information as to the composition of the interior of the earth. Gravitational, geodetic, astronomical, and seismological data, together with the elastic constants of rock materials, provide the basis for an estimate of the density and composition of the earth at various depths. Notwithstanding the enormous pressures within the earth, rocks cannot be squeezed into a volume so small that their density would be sufficient to account for the high density of the earth as a whole. " Beyond reasonable doubt the earth has a metallic core of iron or nickel-iron, the diameter of this core being about one-half that of the earth. Bordering the iron core, moreover, there is a fringe of mixed iron and silicate, and surrounding this is a silicate shell." The earth, except for the practically negligible crust, is then composed mainly of metallic iron and iron-magnesium silicates, and consists almost entirely of the four elements: iron, magnesium, silicon, and oxygen.

Assuming the distribution of matter in the earth as suggested by Adams and Williamson, H. S. Washington (*Amer. Journ. Sci.*, **9**, 1925, pp. 351–78) has attempted to calculate the chemical composition of the earth as a whole from the masses of the core and the various shells, and utilising the most probable estimates of their composition. The percentages of the sixteen most abundant elements in order are: iron, 31·82; oxygen, 27·71; silicon, 14·53; magnesium, 8·69; nickel, 3·16; calcium, 2·52; aluminium, 1·79; sulphur, 0·64;

sodium, 0·39; cobalt, 0·23; chromium, 0·20; potassium, 0·14; phosphorus, 0·11; manganese, 0·07; carbon, 0·04; titanium, 0·02. These elements are all of low atomic weight and atomic number.

Tectonics.—L. Kober has published a condensation of his views on the origin of the greater features of the earth's crust (*Gestaltungsgeschichte der Erde*, Berlin, 1925, pp. 200), which were first given in detail in his *Bau der Erde*, 1921 (SCIENCE PROGRESS, January 1924, pp. 379–80).

The object of S. von Bubnoff's important paper on "Die Gliederung der Erdrinde" (*Fortschr. d. Geol. u. Pal.* Heft. 3, 1923, pp. 84) is to systematise the individual crustal elements according to their geological characters, by analyses of their epeirogenic, orogenic, and magmatic processes. He divides the crust into four main units: 1, permanent continental blocks of constantly rising tendencies; 2, permanent oceanic areas of constantly subsiding tendencies; 3, feebly mobile shelf areas, varying between lowland and shallow sea; 4, highly mobile geosynclinal areas, alternating between deep sea and high mountains. The ancient shields are continental blocks of the first order; the remnants of the Caledonian, Variscian, and other mountain regions are blocks of the second order. Appropriate European examples of each of these crustal elements (except the ocean) are analysed by consideration of their epeirogenic and orogenic characters, their sedimentation, and their igneous history. Fundamental geotectonic questions such as rigidity and plasticity, the structure of subcrustal regions, and the relations of the accompanying igneous activity, are also discussed in an illuminating manner. Of especial value in this paper are the summaries of the geological history, diastrophism, and igneous activity of numerous European crustal units.

In his Presidential Address to the Geological Society of London Dr. J. W. Evans discusses the characteristic of regions of tension in the earth's crust (*Q.J.G.S.*, **81**, pt. 2, 1925, pp. lxxx–cxxii). The evidence for tension is found in jointing, slip (normal) faulting, and in dykes and other characteristic igneous phenomena. Dr. Evans distinguishes between local and regional tensions, and goes on to discuss areas in which regional tension has been operative in post-Permian times. It is shown that the great N.W.–S.E. dyke-swarms of the West of Scotland must represent a considerable extension of the crust, possibly causing a total relative change of distance between Central Europe and Western Britain of from six to twelve miles since Triassic times. This drift is towards an oceanic deep running to the N.W. from the Bay of Biscay to the open Atlantic, the crustal blocks being carried forward by the outward flow of the plastic layer beneath. A discussion of the doctrine of isostasy in relation to the *sial* and *sima* layers and the modes of intrusion and differentiation of magma, follows. The question of the origin of regions of tension is then dealt with, and leads to a favourable consideration of Wegener's theory of continental drift; for which, however, the sliding of land masses towards the hollow of the Central Pacific is regarded as the most probable mode and direction of movement.

R. T. Chamberlin has developed his wedge theory of diastrophism in an important paper (*Journ. Geol.*, **33**, 1925, pp. 755–92). Studies of the depth of folding, laboratory experiments in faulting with analyses of stress-strain relations, and the bilateral symmetry of many mountain systems have led to the conclusion that the wedge-shaped block is the typical form of compressed mountain ranges. The wedge shape and wedge dynamics can be applied to plateaus and the elevation and deformation of continents. Batholiths play but a secondary role in the wedge theory of orogeny. They appear as the cores of the mountain wedges at a late stage of deformation. When in large volume, they may become an important auxiliary agent in helping to drive the overthrust slices towards the margins of the wedge blocks.

The relation of mountain building to igneous action is discussed by Prof. R. A. Daly (*Proc. Amer. Phil. Soc.*, **64**, 1925, pp. 283–307), utilising the hypothesis of drifting or sliding continents as imagined by Taylor and Wegener, and the analogy of solid crusts on moving lava streams (see SCIENCE PROGRESS, October 1925, p. 216). The slipping of the crust becomes possible because it overlies a thick shell of hot basaltic glass, as explained in a former paper (SCIENCE PROGRESS, January 1924, p. 382). Mountain chains are regarded as compressed structures on the downstream sides of "gigantic landslides." Breaking tensions are developed on both the upstream and downstream sides; and the magma beneath, rendered mobile by relief of pressure, is forced up the continental fissures. In the orogenic zone the crust bends downward, and sometimes founders, with the generation of secondary magmas of the batholithic type. Surface vulcanism is explained by the rise of primary basaltic and secondary magmas into the crust, with the emanation of juvenile and resurgent gases, which act as fluxes in volcanoes of the central type.

Metamorphism.—We may notice the publication by P. Niggli of the third and completely rewritten edition of Grubenmann's *Der Kristallinen Schiefer*, under the title *Die Gesteinsmetamorphose*, I. Allgemeiner Teil (Berlin, 1924, pp. 539).

The subject is treated throughout from the thermodynamic and physico-chemical standpoint.

In a paper on the origin of the foliation of syntectic rocks, H. L. Alling (*Amer. Journ. Sci.*, **8**, 1924, pp. 12–32) comes to the conclusion that the foliation of syntectic rocks beneath a sedimentary cover is due to the superimposition of the bedding or foliation planes of the sediments upon the underlying igneous rock, resulting in a syntectic the foliation of which is parallel to these planes.

N. L. Bowen has discussed and criticised the "mineralogical phase rule" introduced by Goldschmidt in connection with contact metamorphism (*Journ. Wash. Acad. Sci.*, **15**, 1925, pp. 280–4). He points out that in all attempts to decide, on the basis of the number of phases, whether equilibrium has been attained in a metamorphic rock, it is essential to bear in mind the fundamental assumptions as to the number of constituents involved.

Dr. C. E. Tilley discusses the various contact metamorphic mineral assemblages which may occur within the system CaO-MgO-Al_2O_3-SiO_2 (*Geol. Mag.*, 62, 1925, pp. 363–7). The assemblages may be classed into three groups: free silica hornfels, quartz- and carbonate-free hornfels, and quartz-free hornfels, with carbonates.

The same writer has traced the successive metamorphic zones characterised by the entry of chlorite, biotite, and almandine respectively, into the pelitic rock types of the Southern Highlands of Scotland (*Q.J.G.S.*, **81**, pt. 2, 1925, pp. 100–12). He shows that these zones succeed one another in order from S.E. to N.W. in the region between the Highland Border and the heads of Loch Lomond and Loch Fyne; and as they recline at low angles to the N.W. they are superposed in an increasing grade of metamorphism. It follows (according to Tilley's view) that the metamorphic zones are inverted, and that the present structural sequence does not represent the disposition of the sediments when the metamorphism took place.

The injection metamorphism of dolomitic limestone of Cambro-Silurian age in the island region of Mögster, south of Bergen, Norway, has been described by N. H. Kolderup (*Bergens Mus. Aarbok*, 1923–4, Naturvid. Raekke, No. 1, 64 pp.). The agents of metamorphism are the Caledonian granites and diorites, which have riddled the limestones in small veins and dykes. Epidote gneiss has been formed by the interaction of the igneous rock and dolomite; whilst numerous silicate minerals, including microcline, have been developed within the mass of the dolomite.

Dr. C. E. Tilley has described some chloritoid rocks

(*Geol. Mag.*, **62**, 1925, pp. 309–18), including a chloritoid-andalusite schist from Eyre Peninsula, South Australia, and chloritoid-phyllites from Tintagel, Cornwall, and discusses the place of chloritoid in progressive regional metamorphism. Chloritoid is stable over a very wide chemical and physical field. The mineral may develop at an early stage of metamorphism, appearing in the chlorite zone ; but it also occurs in association with biotite, and in the still higher zone of almandine. Beyond this grade of metamorphism chloritoid gives place to staurolite.

Physical Geology.—G. Slater has made a number of valuable observations on the rate of melting and the relationship of pressure to internal ice movement in the Nordenskjöld and neighbouring glaciers of Spitsbergen (*Journ. Geol.*, **33**, 1925, pp. 408–46). A definite relation was established between the rate of melting of the marginal ice-cliffs and the air temperature at Bruce City and the Green Harbour Meteorological Station. For each degree Fahrenheit of average maximum monthly air temperature above F.P., the amount of retreat of the ice was 0·5 feet. Directed and concentrated pressure was found to produce movement of névé ice along thrust-planes in the direction of pressure, with contortion and imbricate structure ; but with irregular movement or slides at right-angles to the direction of pressure.

Dr. L. Hawkes describes certain patterns in surface deposits in Iceland, which are attributable to frost action with alternations of freezing and thaw (*Geol. Mag.*, **61**, 1924, pp. 509–13). Among these phenomena are networks in clays ; growth of the curious knolls known as " tuer " in grass land ; the formation of stone rings in rocks which are being shattered by frost ; the formation of similar rings in unevenly-graded deposits ; and the formation of shallow hollows in gravel. These patterns and structures may be preserved in sediments, and may then form valuable indications of ancient climates.

The remarkable polygonal patterns found on the surface of the ground in Spitsbergen form the subject of a detailed paper by J. S. Huxley and N. E. Odell (*Geogr. Journ.*, March, 1924, pp. 207–29). Two types of polygonal structure have often been confused : 1, polygons delimited by borders of large stones and with centres of sticky mud ; 2, polygons separated from each other by cracks, and showing no differentiated distribution of fine and coarse materials between centre and periphery. These are respectively called stone-polygons and fissure-polygons. Under the latter tundra-polygons and mud-flat fissure-polygons are distinguished. The former are due to the formation of ice wedges in cracks ; and the latter to either thawing-contraction, or drying cracks, or both. The stone polygons are due to frost action operating by differential comminution of rock material, by lateral pressure often accompanied by differential transport, and by solifluction.

A very detailed study of marine action and coastal forms is that by D. Johnson in his book, *The New England—Acadian Shore Line* (New York: 1925, pp. 608), The theme of the book is that the Atlantic coast-line of North America suffered a subsidence which culminated only a few thousand years ago, and that ever since it has remained stationary. The subsidence is traceable with increasing depth from Florida northwards, and amounts to more than 1,200 feet. Consequently the whole of the eastern seaboard of North America is a drowned land with a youthful topographic expression. The banks off the coast are explained as old levelled land surfaces recently submerged. Hence the view that the continental shelf represents the base of storm-wave erosion is set aside.

PREHISTORIC ARCHÆOLOGY. By J. Reid Moir, F.G.S., F.R.A.I.

The Proceedings of the Prehistoric Society of East Anglia, vol. iv, part ii, 1924, contains many papers of much interest to students of early man. Messrs. W. H. Cook and J. R. Killick describe (pp. 133–54) an important discovery of a workshop site of late St. Acheul date in the Medway Valley, at a place called Frindsbury, near Rochester. The chalk at this spot is overlain by a calcareous loam, and, in a depression of this deposit, have been found seventeen artificial heaps of flints brought there by the ancient palæolithic people. The floor rests at about 4 feet from the present surface, and 100 feet above sea-level, and contained thousands of humanly shaped flints, among which occurred hand-axes, and scrapers, of late St. Acheul type—great quantities of flakes, some cores, and quartzite hammer-stones. These remains were entirely covered by a dark brown loam which it is thought may represent a remnant of the deposits laid down by the Medway when flowing 100 feet above its present level. The number of artifacts recovered is upwards of 4,000, and the area excavated was about 400 square feet superficial. No organic remains were discovered, and the palæolithic flints, which are quite unabraded and sharp, exhibit varying colours ranging from greyish-white to blue, while some show the well-known "basket-work" patination which is such a constant feature upon flints of this, and similar ages, in England, and upon the Continent. It is evident from this discovery that considerable geological changes have taken place since the Acheulean hunters occupied the Medway Valley. In an appendix to the paper Mr. Cook gives an abbreviated account of the finding of the Halling human skeleton of Aurignac age in the same valley.

For many years past opinion has been divided as to whether the Harrisonian eoliths occurred actually *in situ* in the high-level drift of the Kent plateau, and it is therefore of much interest to note that the late Mr. de Barri Crawshay (pp. 155–62), by means of excavations carried out in this deposit, has shown that these specimens do indeed occur in it. A pit was sunk at South Ash (500 ft. O.D.), and the following section exposed: humus 1 ft. 3 in. passing into grey, loamy clay which, at a depth of about 2 ft., becomes very ferruginous, with flints and some eoliths, massed at its base; at the 4-foot level occurs another closely packed seam of flints, and in it one or two eoliths were found; at 5 ft. 9 in. the clay becomes very gravelly, and was dug to a depth of 7 ft. 6 in. The specimens found by Mr. de Barri Crawshay are typical Harrisonian eoliths, being made from tabular-shaped pieces of flint, exhibiting rough flaking round the edges, which has given them a definite pointed form. No palæolithic implements of any description were found in the diggings.

The presence of Upper Palæolithic flint implements in East Anglia, though disbelieved in by some archæologists, is being confirmed by many widely-scattered discoveries, and Prof. J. E. Marr, F.R.S., describes (pp. 163–4) a *burin*, or graving-tool, found by Mr. Frank Barclay of Cromer, upon the surface at Higham, Suffolk. This specimen, which shows that the graving-edge had been renewed by flaking, probably more than once, is in every way comparable with a *burin* figured by Commont and found at Renancourt near Amiens, and believed by him to be referable to a period between the cultural phases of Aurignac and Solutré.

Mr. J. E. Sainty (pp. 165–176) describes a flaking site found by him on Kelling Heath, near Weybourne, Norfolk. The site of the discovery is on the edge of the high ground overlooking the North Sea, and the ancient occupation level lay under 10 or 11 in. of surface material and rested, mainly, on the underlying glacial gravel. About 3,000 artifacts were taken away by Mr. Sainty for examination, and he concludes that they represent a phase of the *Tardenois* culture which connects the end of the Palæolithic period with that of the earliest Neolithic. Some of the Kelling specimens are very small and minutely worked, but with them were found other and larger implements, comprising scrapers, prismatic tools, and a large oval hand-axe. Further excavations at this site will be looked for with interest.

Mr. Leslie Armstrong (pp. 182–202) has been continuing his excavations at the famous flint mines at Grime's Graves, Norfolk, and records further discoveries in the archaic pits in the chalk he has opened up in the dry valley at this place. The pits now being investigated are, it would seem, of a considerably earlier date than the majority situated in the nearby plateau, and, it is clear, exhibit a much more primitive manner of mining. Thus, they are smaller, and less symmetrical than the later excavations, and were dug out by means of pieces of bone held in the hand and used as picks, while the more experienced miners utilised the antlers of the Red Deer for this purpose. Further, the system of galleries radiating from the base of the main shaft, which is such a marked feature of the later pits, is almost entirely absent in the earlier examples. The flint implements recovered are not very numerous, but are chiefly of palæolithic types, as is certainly the case with those recovered recently in some of the flaking sites at Grime's Graves.

Mr. J. P. T. Burchell (pp. 203–10) gives an account of the deposits he has investigated at Reculver, Kent, which appear to range in date from the Neolithic to the Early Iron Age.

Mr. Cyril Fox (pp. 211–33) gives an interesting account of an Early Iron Age settlement at Abington Pigotts, Cambridgeshire, which was continuously inhabited from about 400–250 B.C. to probably the end of the fourth century A.D.

All the above-mentioned papers are adequately illustrated, and the part under review well sustains the reputation acquired by this Society since its inauguration.

BOTANY. By E. J. Salisbury, D.Sc., F.L.S., University College, London.

Anatomy.—From a study of various species of *Selaginella*, C. W. Wardlow finds evidence that the size and arrangement of the steles in that genus are to some extent correlated with the size of the stem. Thus in general the number of steles present in the erect axis of *S. lyallii* increases with its diameter, whilst the width of the median stele in polystelic types varies with the size of the axis. The polystelic condition is thus perhaps conditioned more by physiological necessities than by phyletic relationships (*Trans. Roy. Soc. Edin.*, p. 281, 1925).

Suppression of the vascular tissue, or a defective vascular supply in the nodules of *Vicia faba*, apparently results when plants are grown in media deprived of boron (*cf.* Brenchley and Thornton, *Proc. Roy. Soc.*, p. 281, 1925).

The anatomy of the haustoria of a large species of *Cuscuta* has been studied by Thompson (*Trans. Roy. Soc. Edin.*, p. 343, 1925). Here, as in other species, the haustorium is preceded by a cushion whose central cells serve to penetrate the host. The haustorium itself, which is regarded as a modified root, grows through this pre-haustorium and develops absorptive processes which are interpreted as root hairs. These processes when they came in contact with the wood of the host differentiate as tracheids, but no connection with the phloem was found nor were any phloem elements recognised in the haustorium. The tracheids would thus appear to perform a dual function.

P. Tate, who has investigated the Broomrape (*Orobanche hederæ*) (*New. Phyt.*, Dec. 1925) finds that the sieve tubes of host and parasite join in an end-to-end manner, and that the xylems are connected by short tracheids. Germination only takes place in the presence of roots of the host, and the young plant appears to pass the first year below ground, coming up in the May following germination.

An anatomical study of the cyathium of *Euphorbia* (Huper. *Ann. Bot.*, Oct. 1925) confirms the view that it is a reduced cymose inflorescence. Each " gland " represents a pair of modified inflorescence branches fused with parts of the adjacent involucral bracts, whilst the disc beneath the ovary has an anatomical structure consistent with the view that it is a reduced perianth.

Ecology.—Experiments carried out by Macintire and Shaw (*Soil Science*, Nov. 1925) indicate that the rate of leaching of calcium carbonate from the soil takes place more rapidly from the subsurface than from the superficial layers. An important paper by O. C. Magistad in the same journal (Sept. 1925) emphasises the part played by real acidity in determining the nature and amount of plant growth. It is shown that the solubility of the toxic salts of alumina is directly dependent on and proportional to the soil reaction. Only small quantities are present in solution between *p*H. 4·7 and *p*H. 7·8. The toxicity of soils more acid than *p*H. 5 is almost equally due to the direct effect of acidity and the indirect effect in rendering the alumina soluble. Strongly alkaline soils also contain considerable amounts of soluble alumina.

Heilbrom (*Svensk. Bot. Tid.*, pp. 153–69, 1925) has studied the osmotic pressure of various cushion plants growing in the Paramos of Ecuador where the soil temperature (3,650 m.) varies between 9° and—13°·5 C. The annual variations of temperature are small, but the diurnal variations are large. The lower parts of the matlike cushions die but, owing to the low temperature, do not decay, and produce a phanerogamic equivalent to the *sphagnum* bog. The Paramos herbs have an average osmotic pressure of about 20 atmospheres, the bushes 25–29 atmospheres. At the lower level of Quito the osmotic pressure of the herbs ranged from 12–21 ats. and of the bushes 25–32 ats. A series of peat samples from the Isle of Man examined by Erdtman (*Liverpool Geol. Soc.*, p. 158, 1925) show a preponderance of birch pollen and a small amount of pine pollen at the lower levels, whilst the higher levels contain pollen of hazel, alder, elm, and oak.

Wlodek and Strzemienski have examined the hydrogen-ion concentration on a number of localities for various plant associations in Poland. *Vaccinietum myrtilli* showed a range of *p*H. 3·4–3·91, *Dryadetum octopetalæ* 5·3–6·6, *Nardetum strictæ* 3·8–6·0. *Pinus montana* association on siliceous soil yielded 3·4–3·9, whilst on calcareous soils the range was 5·3–6·1. There appeared to be no relation between *p*H. value and altitude (Cracovie, 1925).

Experiments by Marie Dietrich on the transpiration of sun and shade leaves appear to indicate that "shade species," even when growing in the sun, have a lower transpiration in relation to evaporation than "sun species." "Shade individuals" have a larger transpiration per gram of fresh weight than equivalent "sun individuals" (*Jahrb. f. wiss. Bot.*).

Taxonomy, etc.—New species of Compositæ are described by Sherff (*Bot. Gaz.*, Dec. 1925) and by Moore (*Proc. Linn. Soc.*, Dec. 1925). In the *Journal of Botany* (Aug.–Dec. 1925) a large number of new species are described from Malay. These include members of the following genera: *Ficus*, *Artocarpus*, *Conocephalus*, *Ammora*, *Ormoria*, *Wedelia*, *Pellionia* (S. Moore), *Eria*, *Calanthe*, *Phalænopsis*, *Sarcanthus*, *Forbesina* (a new orchidaceous genus), *Ophiopogon*, *Forrestia*, and *Pinanga* (Ridley). In the same journal for December Salmon and Wheldon furnish a useful clavis of the British species of *Erythræa*, of which they recognise eight as distinct. In the January number R. Good describes the geographical distribution of the species of *Cassiope* and *Phyllodoce*. It is suggested that the origin of the latter may have been in the mountains of America and that of *Cassiope* in the mountains of Asia.

Cryptogams.—Magrou has investigated the endophytic fungus which is present in the region of the midrib of *Pellia epiphylla* (*Ann. d. Sci. Nat.*, Dec. 1925). He finds that the sporophyte is generally free from the fungus, and indeed where the gametophyte is badly infected the fungus degenerates in the neighbourhood of the archegonia and sporophyte, suggesting an inhibitory influence. The fungus destroys the chloroplasts in the attacked cells. Uninfected thalli were successfully cultivated, on sterile media having an acid reaction, and attained to a larger size than infected thalli of corresponding age; moreover, they exhibited continuous growth as contrasted with the intermittent growth of infected thalli. In the same journal Arnaud contributes a taxonomic study of the Asterinees. An enumeration of the Leicestershire Algal Flora by Miss Rich is concluded in the December *Journal of*

Botany, and Paulson describes a new lichen belonging to the genus *Ansia* from Malay.

Genetics.—The transmission of white tissue in *Pelargonium* is, according to experiments carried out by Chittenden (*Genetics*, Nov. 1925), dependent on both parents, whilst in *Hydrangea* the inheritance of variegation is strictly maternal. The chlorophyll defect is attributed to extra-nuclear substance, possibly plastids, which in *Pelargonium* are probably transmitted by the pollen. Variegated seedlings of *Hydrangea* never occur.

ZOOLOGY. By Reginald James Ludford, D.Sc., Ph.D., University College, London.

The Macronucleus and New Morphological Characters in Infusoria.—The macronucleus of the Infusoria has been regarded as controlling the various vegetative functions of the organism, while the generative function is under the control of the micronucleus. As the result of a study of the relationship of the macronucleus to the formation of short spurs on the spines of *Diplodinium denticulatum*, V. A. Dogiel concludes that the inherent tendency to the formation of spines is regulated and localised under the direct influence of the macronucleus. He considers that " the case described gives convincing evidence of the bearing of the somatic nucleus on the origin and localisation of new morphological characters in Infusoria (*Q.J.M.S.*, vol. 69, 1925).

Spermatogenesis.—The spermatogenesis of *Peripatus* is a problem of special interest, not only on account of the phylogenetic position of this arthropod, but also because it has been said that the spermatozoon is unique in that it is devoid of cytoplasmic substance. J. Brontë Gatenby has therefore reinvestigated the spermatogenesis of *Peripatus*, employing the modern technique of cytology. He finds that the spermatozoon has a true acrosome, which is formed from a Golgi body. Most of the mitochondria of the spermatid, but not all of them, go to form a " nebenkern " sphere, which is a reticulate formation, closely resembling a nucleus in appearance. The middle-piece contains, in addition to a centrosome, a lipin part, probably derived from certain of the finer mitochondria left over when the " nebenkern " was formed (*Q.J.M.S.*, vol. 69, 1925).

A useful summary of the recent work on the part played by mitochondria in sperm-tail formation is contributed by V. Nath to the same journal (*Q.J.M.S.*, vol. 69, 1925). Nath also records some original observations on spermateleosis in moths, scorpions, and centipedes, and supports Bowen's interpretations both with regard to the sperm-tail in moths and the formation of the mitochondrial nebenkern.

Oögenesis.—An important contribution to our knowledge of the oögenesis of the fowl has been made by F. W. Rogers Brambell, who has succeeded in demonstrating for the first time within the oöcyte of *Gallus*, a typical Golgi apparatus surrounding the centrosphere. During oögenesis an extraordinary process occurs, which is so far unique: there is an extrusion of the Golgi apparatus from the follicle cells into the oöcyte. Apparently, all the Golgi elements eventually break up into fine granules, which become scattered throughout the cytoplasm. Brambell suggests that these granules persist as such during maturation and fertilisation, and become included in the embryonic cells during segmentation. Later they may give rise to the typical form of the Golgi apparatus by a process of condensation. During growth of the oöcyte the mitochondria increase in number. Later they collect to form a mitochondrial cloud, inside which there arises the temporary mitochondrial yolk body. This eventually breaks up to form mitochondria that are scattered throughout the oöplasm. Most of the yolk is formed by the direct transformation of mitochondria, although another kind of yolk is formed in vacuoles around each transformed mitochondrial spherule. It is also suggested that fat globules are formed under the influence of the Golgi bodies (*Phil.-Trans. R.S.*, B, vol. 214, 1925).

Brambell's observations are supported by the previous ill-understood work of Marie Loyez, and the more recent work of Bhattacharya, on Reptiles, in a Thèse de Paris, 1925.

Micro-injection Studies on Marine Eggs.—In a paper on "The Hydrogen-ion Concentration and Oxidation-reduction Potential of the Cell-interior before and after Fertilisation and Cleavage," J. and D. M. Needham describe an experimental investigation which they have carried out with certain marine eggs, by means of the micro-injection technique. Altogether 3,300 eggs were injected with indicators, and these eggs included those of four echinoderms, one tunicate, and one polychæte worm. The internal pH of all the eggs studied was in the neighbourhood of 6·6. No change was found on fertilisation, the pH remaining constant up to the sixteen-cell stage. The rH of the eggs varied more than the pH (between 19 and 22), but there was no difference on fertilisation, or cleavage, as far as the eight-cell stage (*Proc. R.S.*, B, vol. 99, 1926).

Placentation.—In a paper "Contributions to our Knowledge of the Structure of the Placenta of Mustelidæ, Ursidæ, and Sciuridæ," A. Subba Rau has given an account of the form and structure of the placenta in certain species, which have not previously been studied (*Proc. Z.S.*, 1925). Some interesting suggestions are put forward with regard to the evolution of the placenta. The zonary type of placenta of the Dog and

Cat is regarded as the primitive type of Carnivore placenta. The double-discoidal placenta of *Putorius furo*, and *Zorilla striata*, and the discoidal placenta of the Bear are considered to be derived from the zonary type, and to be of a more specialised character. The placenta of *Xerus* was found to be a simpler organisation than that of other Rodents so far studied.

A start has been made in the study of the placenta in tissue cultures by V. Plješakov, who has cultivated tissues of the placenta of the rabbit *in vitro*. The trophoblastic syncytium apparently degenerates, but giant cells are formed from the cellular layer of the trophoblast. These cells pass out into the culture medium (*Jour. Expt. Zool.*, vol. 42, 1925).

Secretion in the Epididymis.—The origin of secretory products in glandular cells has been the subject of a great deal of discussion. Recent researches have shown that the Golgi apparatus plays an important part in the process of secretion, and in many cases secretion granules or droplets have been found to form in intimate relationship with the apparatus. In a recent paper, R. J. Ludford has described the secretory process in the epididymis. Although the secretion first makes its appearance in the cells in the region of the Golgi apparatus, there are morphological changes in the other cell organs. Thus variations occur in the basophility and oxyphility of the nucleolus, nucleolar extrusions take place, and there are variations in the mitochondrial content of the cells. These changes emphasise the fact that the cell is a functioning unit, the integral parts of which are all concerned in physiological processes (*Proc. R.S.*, B, vol. 98, 1925).

The Problem of Connective Tissue Ground Substance.—Those who have investigated the development of connective-tissue ground substances during embryogeny have expressed conflicting views as to its origin. The earlier workers concluded that the ground substance arose as an intracellular product, by a transformation of cell processes. Recently, however, evidence has been brought forward which indicates an intercellular origin. G. A. Baitsell has worked on this problem with chick embryos. He studied serial sections and employed a modified form of micro-dissection. It was found that previous to the appearance of the mesenchyme cells, there is a transparent gelatinous, cell-free ground substance, which pervades the embryonic body from very early stages of development. At first this substance contains very few fibrils, but later there is a progressive increase in fibrillation. Mesenchyme cells invade the fibrillated area, and Baitsell compares this process to the movement of cells in a tissue culture set up in a plasma medium (*Q.J.M.S.*, vol. 69, 1925).

Essentially similar results have been arrived at by R. G. Harrison, who investigated the development of the balance in *Amblystoma,* by the method of transplantation. He says that " the balancer membrane thus affords a clear proof that connective-tissue fibres take origin in an amorphous ground-substance, independently of any direct action on the part of the mesenchyme cells " (*Jour. Expt. Zool.*, vol. 41, 1925).

Ticks and the Spread of Cattle Disease.—Heart-water is a disease affecting sheep, goats and cattle in South Africa, and has been said to be caused by an ultra-microscopic virus which is transmitted by the bont-tick. E. V. Cowdry has succeeded in demonstrating that a gram-negative, intracellular coccus-like organism occurred in all cases of the disease, and was definitely related to the febrile reaction. Cowdry terms this organism *Rickettsia ruminantium.* It is a typical endothelial parasite, being restricted in distribution to the endothelial cells of the smaller blood-vessels, and to portions of such elements which have broken off into the blood-stream. The same organism has also been demonstrated in the ticks which transmit the disease. " When larvæ which had taken no food since hatching were allowed to feed upon cases of heart-water, they acquired *Rickettsiæ* which appeared to be identical with those in the tissues of animals suffering from heart-water, whereas control larvæ hatched from eggs deposited by the same female and fed on normal animals remained free from *Rickettsiæ.* After larvæ presumably infective had moulted, the resultant nymphæ containing *Rickettsiæ* in their alimentary tracts, when fed upon susceptible animals produced in them typical attacks of heart-water, which the control nymphs, devoid of *Rickettsiæ,* failed to do." Histological examination of the tissues of animals infected in this way showed the presence of the typical *Rickettsiæ* (*Jour. Expt. Med.*, vol. xlii, 1925).

Morphology of the Myxinoid Fishes.—F. J. Cole has published in the *Transactions of the Royal Society of Edinburgh* (vol. liv, 1925) a further contribution to his series of studies on " the general morphology of the Myxinoid Fishes, based on a study of Myxine." The principal interest in the present work is the description of the venous system, and the so-called veno-lymphatic spaces, upon which little work has been done in the past. The main anatomical relationships are clearly shown by means of excellent diagrams.

ENTOMOLOGY. By J. Davidson, D.Sc., Rothamsted Experimental Station, Harpenden.

General Entomology.—A brief survey of the history of Entomology is given by R. Adkin (*Proc. South London Entom. Nat. Hist. Soc.*, 1924–5, 28–44), entitled, " Entomology, Ancient and

Present Day." *Concerning the Habits of Insects* is the title of a book by F. Balfour Browne (The University Press, Cambridge, 1925, pp. 1–166, 6*s*. net.). This book is the outcome of a course of lectures " adapted to a juvenile auditory " delivered at the Royal Institution during the Christmas holidays 1924, and indicates the interest and pleasure to be derived from observations on and the collecting of insects as a means of gaining an insight into their natural history and habits : the final chapter deals with the habits of insects in relation to the work of man. A. Barbey has brought out a second edition of his book, *Traité d'entomologie Forestière* (Berger-Levrault, Paris 1925, pp. xviii + 721, 496 figs.), which first appeared about ten years ago ; the insects which cause damage to the more important forest trees are dealt with under the trees concerned ; a chapter on useful insects is included and a bibliography of six pages.

The development of insects in relation to their environment is a subject of great biological importance, and the effect of temperature and its relation to humidity appear to be the most important factors. F. S. Bodenheimer (*Bull. Soc. R. ent. Égypte*, Cairo, 1925, 149–57) discusses this question in relation to predicting the developmental cycles of insects : the theory that the product of temperature in degrees centigrade and the period of development in days is constant is disproved, and Blunck has recently introduced a modified formula in which the product of the duration of development and the difference between the surrounding temperature and the critical cold point is considered as constant ; the time of development in relation to the surrounding temperature forms an equilateral hyperbola ; if for each of two temperature points on this hyperbola, the corresponding duration of development is known, it is possible to construct the whole curve, and for any other temperature point between the critical heat and cold point the corresponding duration of development is known. This question is also discussed by the same author (*Centralbl. Bakt. Paras. Infekt.*, Jena, 1924, **93**, 474–80) and by E. Martini (*Zeitschr. f. angew. Ent.*, xi, 301–5).

J. H. Comstock has a second complete edition of his textbook *An Introduction to Entomology* (Comstock Publ. Co., Ithaca, N.Y., 1925, pp. xix + 1044, 1,228 figs.) : Part I of this work, which deals with the structure and metamorphosis of Insects, was first published separately in 1919 ; Part II deals with the classification and life histories of insects, twenty-five orders being recognised. *A List of British Aphides* (Longmans, Green & Co., London, 1925, pp. ix + 176, 12*s*. 6*d*. net.), by J. Davidson, in the series of Rothamsted Monographs on Agricultural Science, deals in the form of a species list with the aphides of Britain, their food plants and distribution as recorded in the British Isles, together with some notes on synonymy and a food plant index ; an extensive bibliography is also given.

C. S. Elton (*Trans. Entom. Soc.*, London, 1925, 289–99) has some notes on the dispersal of insects to Spitzbergen ; of particular interest is the finding of large numbers of winged Aphides (*Dilachnus piceæ* (Pz.)) which apparently had been carried some 800 miles from the Kola Peninsula, this being the nearest area where its food plant, spruce (*Picea*), occurs. The results of the collections of insects made by the third Oxford University Expedition to Spitzbergen in 1924 are given in the *Ann. Mag. Nat. Hist.*, xvi, as follows : Diptera (Cyclorrhapha), by J. E. Collin (332–7) ; Diptera (Nematocera), by F. W. Edwards (354–6) ; Coleoptera and Lepidoptera, by C. S. Elton (357–9), the collections made by previous expeditions having already been recorded in earlier volumes of the same journal.

A *Syllabus der Insektenbiologie* (Gebr. Borntraeger, Berlin), edited by H. Blunck, with the assistance of many entomologists, is promised to appear in parts from time to time. Part I, dealing with a portion of the Coleoptera and consisting of 136 pp., has appeared ; in a very abbreviated manner, with the aid of indication lettering, certain information is collected together with reference to the species, families, and genera ; the number of species and genera are given, and notes on the geographical distribution, habitat, food, etc., etc., of the adult and larvæ. The task is a very big one, and it will doubtless be a long time before the complete series of parts are published.

An alphabetical list of the papers dealing with Indian Entomology, published during 1924, is given in *Bull.* 161, *Agric. Res. Institute,* Pusa, 1925, pp. 1–41. H. Gadeau de Kerville (*Bull. Soc. Ent. Fr.*, 1925, No. 4, 75–9) has some interesting observations on experiments on the regeneration of the antennæ in *Tenebrio molitor* L. (Coleop.) : after amputation of certain segments of the antennæ, some individuals completed their development and the adults had completely regenerated antennæ ; also with young individuals of the phasmid, *Carasius morosus* Br. of which either one or both of the antennæ were partially or wholly cut off, one or two individuals developed in which a tarsus with claws or other leg-features appeared in place of the amputated antenna ; in some cases normal regeneration of the antennæ occurred. The same author has a note (*loc. cit.* 79–80) on some results obtained by the decapitation of the larvæ of *Vanessa urticæ* L. and *Sericaria mori* L. ; of sixty caterpillars of the former species, after the head had been cut off at the time of nymphosis, one specimen completed its development, but died without being able to emerge from the nymphal sheath ; it lacked a head, but had normal wing coloration. In the case of *S. mori* L., out of about 150 larvæ decapitated at the time of nymphosis, five individuals completed their development to the imago stage (without heads) and partially emerged from the nymphal sheath, and two laid eggs. The author has made some earlier observations on this question (*Bull. Soc. Ent. Fr.*, 1923, 229; 1924, 69), and also L. Cuenot (*C. R. Acad. Sci.*, Paris, 1921, Séances April 18 and 25).

Our knowledge of the migration of insects is somewhat scanty, and new records relative to this question are always of interest. C. B. Williams (*Trans. Entom. Soc. London*, 1923, 207–33; 1024, 439–61) gives some records he has obtained and discusses certain aspects of the problems involved.

Orthoptera.—W. N. Makalowskaja (*Zool. Anz.*, 1925, **64**, 295–306) has some biological notes on *Locusta migratoria* L., with observations on the forms *migratoria* and *danica*. A paper on respiration in grasshoppers by M. O. Lee (*Jl. Exper. Zool.*, 1925, **41**, 125–54) discusses the question whether respiration is produced by alternate influx and efflux of air through the spiracles or by a definite circulation of air through the tracheal system, some spiracles being concerned with inspiration and others with expiration. In nine species of grasshoppers experimented with, the author found that the two pairs of thoracic spiracles and the first two pairs of abdominal spiracles are concerned with inspiration, while the last six abdominal spiracles have an expiratory function. The air is taken in through the former spiracles and pumped out through the latter, the valves in the anterior spiracles I–IV being opened during inspiration while the remaining spiracles are kept closed, the reverse taking place during expiration.

Coleoptera.—D. E. Fink (*Biol. Bull.*, 1925, **49**, 381–406) has investigated the question of the storage of nutrient substances and the method of utilisation of these substances during the progress of hibernation in the well-known potato-beetle, *Leptinotarsa decemlineata* Say: the phenomenon of hibernation in insects is of great interest, as it may occur with different species in practically any stage of the life cycle; the author finds that in the potato-beetle preparation for hibernation follows a period of extensive feeding and consists in an accumulation in the adipose tissues of 29 per cent. of fat; the greatest depletion of fat occurs during the first few months of hibernation, and in the metabolism of the fat body, the fat is replaced by albuminoid granules and other products, the respiratory quotient being lowest during the first few months of hibernation and highest at the termination of the dormant period.

J. C. M. Gardner (*Indian Forest Records, Entom. Series*, 1925, **12**, Pt. 2, 1–7) has the first of a series of papers which will deal with the characters of the immature stages of Indian Cerambycidæ, with the view of enabling early larval stages of species to be definitely determined; the egg, immature and mature stages of the larva and pupa of three species of considerable economic importance are described, and the mature larvæ of three other species.

An account of the life-history and habits of the Death-watch Beetle (*Xestobium tesselatum*), which causes damage in the timbered roofs of old buildings, is given by H. M. Lefroy (*Pubn. Society of Antiquaries*, London, 1925, 1–8, 3 figs.): the beetles appear in May or June, emerging from dying oak trees or from building timbers and the tapping sounds they make before mating is the origin of the popular name given to the insect; the female may lay as many as eighty eggs in crevices of the wood, and the grubs burrow into the wood, where they feed and make tunnels which weaken the timber; in the third summer they come nearer to the surface and pupate and later in the autumn the beetles develop and emerge in spring, but in warm buildings sometimes earlier: the control measure recommended is to spray the wood with a fluid, which gives off a vapour, so destroying the grubs inside the tunnels and at the same time a thin film of poison adheres to the surface of the wood which kills the emerging beetles.

The curious coleopterous larvæ which are found in the tropics, known as trilobite larvæ, have been very little studied and their correct systematic position has been somewhat doubtful; the paper by E. Mjoberg (*Psyche*, 1925, **32**, 119–58) is therefore of especial interest, in that this author describes the first definitely known adult male and female of this group. Several forms from Borneo have been studied, a large number of the insects having been kept under observation; it appears that in Borneo the trilobite larvæ commonly met with are female larvæ of Lycid beetles of various genera; the females are neoteinic in so far that when adult they retain complete larval characters, only differing in their organisation by possessing developed ovaries and a sexual duct and sexual opening; the males on the other hand are well developed beetles exhibiting Lycid characters: copulation takes place in the normal manner. Several types of trilobite larvæ found in Borneo are described and a new genus *Duliticola* erected with *D. paradoxa* sp. n. of the family Lycidæ. The author is of the opinion that no definite convincing statement regarding luminous Lycids is in the literature, although it has been stated that trilobite larvæ are luminous.

R. Jeannel (*Arch. Zool. Exp. et. Gen.*, **64**, 1–84) deals with the question of the morphology of the elytra in members of the Adephaga.

Lepidoptera.—A new organ found in certain Lepidoptera which was named Chætosoma by K. Jordan (*Novit. Zool.*, 1923, 155–8) has been studied by H. Eltringham (*Trans. Entom. Soc.*, London, 1925, 7–9): in Geometridæ and Uraniidæ it consists externally of two small patches of unsealed chitin on top of the head behind the antennæ and a preliminary account of its structure is given; its function is not clear. W. T. M. Forbes (*Mem.* 68, *Cornell University Agric. Expt. Station*, 1923, 1–729, 439 figs.) has a big paper on the Lepidoptera of New York and neighbouring States, the object of which is to enable these insects to be more easily recognised and to assemble information on their life histories: the Microlepidoptera, Pyraloids, and Bombyces are dealt with. J. H. Gerould (*Jl. Expert Zool.*, **42**, 263–86) describes a gynandromorph of *Colias eurytheme* var. *alba*, the offspring of a white mother heterozygous for the dominant white female coloration and a father homozygous for recessive orange-yellow female coloration; the left side of the body and left wings are completely male including a testis having ripe spermatozoa; the right side is female having smaller eye, female colour pattern, an abortive oviduct, seminal vesicles, etc.; Morgan's theory of lagging behind and suppression of a sex-chromozome in the first cleavage is a possible explanation of the gynander being ZZ or male on the left, and Z or female on the right, but an alternative hypothesis is advanced. D. E. Minnich (*Jl. Expt. Zool.*, **42**, 443–469) shows by experiments with *Vanessa antiopa* L. that the larvæ respond to appropriate sound stimuli by throwing the anterior third part of the body dorso-laterally or dorsally: the response to sounds increases with the age of the larvæ and the evidence indicates that the sense organs concerned in this response are widely distributed over the body. W. Speyer (*Zeitschr. f. angew. Entomologie*, 1925, 395–9) indicates the results of some experiments on the effect of arsenic on certain lepidopterous larvæ: compounds containing arsenic are used as stomach poisons for destructive caterpillars and grubs; the author's preliminary results indicate that weak doses may, however, be beneficial in the case of certain diseases of silk worm larvæ.

Hemiptera.—Three papers dealing with Coccidæ and aphides are: Inokichi Kwana (*Dept. Finance, Japan Imp. Plant. Quarantine Service*, 1925, Techn. Bull. 3), the third paper on the "Diaspine Coccidæ of Japan"; Takahashi R. (*Dept. Agric. Govt. Res. Inst. Formosa, Japan*, 1925, Report 16, 1–65) on the "Aphididæ of Formosa," Pt. 4; P. W. Mason (*Proc. U.S. Nat. Museum*, 1925, 67, 1–92), a revision of the aphid genus *Amphorophora.* The morphology of the male genitalia in Rhynchota is the subject of a paper by H. Singh-Pruthi (*Trans. Entom. Soc. London*, 1925, 127–256), and the same author gives an account of the development of the genitalia in some members of this group (*Quart. Journ. Micr. Sci.*, **69**, 59–96). G. Teodoro (*Redia*, 1925, **16**, 13–16) describes the hooking apparatus of the elytra and wings in certain Heteroptera. Seven new species of Heteroptera are added to the fauna of Galapagos Islands, twenty-one species being hitherto listed; a new species of *Halobates* from neighbouring waters is also described by H. G. Barber (*Zoologica*, 1925, **5**, 241–54). C. P. Clausen (*Univ. California Pubns. Entomology*, 1925, **3**, No. 2, 253–88) gives an account of the life-histories of the mealy bugs of the grape and their natural enemies. A. Tullgren has published the second part of his *Aphidologischen Studien*, the first part of which appeared in 1909; a new genus *Gootiella* with *G. tremulæ* n. sp. is erected (*Contrib.* No. 280, *Centralanstalten för försöksvasendet på Jordbruksområdet*, 1925, *Entom. Adv.* 44, 1–70).

Hymenoptera.—A new volume in the *Faune de France* series by L. Berland (Paul Lechevalier, Paris 1925, pp. viii + 364, with 663 text figs.) deals with the five families of the fossorial forms of wasp-like Aculeates, namely, Sphegidæ, Pompilidæ, Scoliidæ, Sapygidæ and Mutillidæ, some 450 species being described with generic and specific keys and biological notes. A publication of the Ministry of Agric. and Fisheries (*Misc. pubn.*, No. 44) gives a useful clear account of the seven species of wasps of the genus *Vespa* with a coloured plate of the species and notes on the life-history and biology. A. D. Peacock (*Br. Jl. Expt. Biology*, III, 61–84) gives a further account of his studies on parthenogenesis and sexuality in Saw-flies (Tenthredinidæ). The Myrmicophiles found in association with the tree-ant *Acanthomyops* (*Donisthorpea*) *brunneus* Latr. include about thirty species of insects belonging to six different orders, H. Donnisthorpe (*Entom. Record*, 1925, **36**, 121–2; 133–9). The parasite *Aphelinus mali* (Hald.) is attracting some attention in economic entomology because of its possible value in suppressing the well-known woolly apple aphis, and R. Schander and O. Kaufmann (*Zeitschr. angew. Entom.*, 1925, **11**, 386–94) give an account of its introduction into Germany from South America, together with certain details regarding its development. P. H. Timberlake (*Univ. California Pubns. Entomology*, 1924, **3**, 223–51) describes five primary and four secondary encyrtid parasites (Chalcidoidea) of *Pseudococcus maritimus* and Tei Ishii (*Dept. Finance, Imper. Plant Quarantine Service*, Japan, *Techn. Bull.*, **3**, 21–30) describes several species new to science from scale insects and aphides including a new genus *Pareusemion*.

Diptera.—F. W. Edwards, in a paper on British Mycetophilidæ, gives a revised generic classification of the group, ten sub-families being recognised (*Trans. Entom. Soc.*, London, 1924, 505–662) and a synopsis of the British Bibionidæ and Scatopsidæ (*Ann. Appl. Biol.* 1925, **12**, 263–75). An important paper by S. W. Frost (*Cornell Univ. Agric. Expt. Station, Mem.* **78**, 1924, 1–228) deals with the leaf-mining diptera of N. America. The mining habit is regarded as having developed from the scavenging habit ; 287 genera and 589 species of N. American plants are affected by leaf-mining diptera and 11 genera and 61 species of diptera are recorded ; biological and descriptive accounts of these species are given and a list of the leaf-mining diptera of the world classified under the names of the plants and insects, together with an extensive bibliography.

A further volume in the *Faune de France* series by J. J. Kieffer (Paul Lechevalier, Paris, 1925, 1–138, 83 figs.) is a monograph on the Ceratopogoninæ. T. W. Kirkpatrick (*Egyptian Govt. Press*, Cairo, 1925, pp. vi + 224) deals with the Mosquitoes of Egypt, being the results of a survey of that country undertaken at the instance of the anti-malarial Commission. There are comparatively few mosquitoes in Egypt ; twenty-two indigenous species are recorded, six being new to the fauna and three species new to science ; the larvæ and pupæ of these species (except one) are here described and figured : the fact that Egypt is surrounded by desert probably accounts for the comparatively few mosquitoes in the country, the areas where they are most prevalent being on the oases of the Western desert ; the control measures undertaken by the Suez Canal Co. during the years 1901–3 resulted in the eradication of mosquitoes and the disappearance of malaria in the Ismailia area.

Eight numbers of the important work on Diptera of E. Lindner, *Die Fliegen der Palæarktischen Region*, Stuttgart 1924, have appeared, the last four dealing with the Tabanidæ. T. Pleske (*Bull. Ent. Soc. Fr.*, 1925, 166–7) describes a new dipteron *Stratioleptis czerskii* belonging to a new sub-family Stratioleptinæ, three males and ten females having been found in Eastern Siberia. I. M. Puri (*Parasitology*, 1925, **17**, 295–369) has two lengthy papers on the life-history and structure of the early stages of Simuliidæ ; the habits of the larvæ and pupæ are discussed and the external and internal anatomy of *Simulium nölleri* Fried described ; a key for the determination of species of British Simuliidæ is given and the morphology of the larva and pupa of several species described. The same author (*Ann. Mag. Nat. Hist.*, **16**, 503–8) has a paper on the structure of the larval stages of *Leptohylemyia coarctata* Fall. J. J. Roberts (*Ann. Trop. Med. and Parasitology*, 1925, **19**, 81–9) gives some observations on *Hippobosca equina* in North Wales. This fly attacks horses and cattle, but in that region it occurs almost entirely on cattle: the presence of bracken with a plentiful supply of decaying humus is the normal habitat for the deposition of the larvæ and the presence of bracken, together with abundant sunshine, are important factors affecting pupation; the flies are generally found from May to August, mating occurring on the animals. L. G. Saunders (*Parasitology*, 1925, **17**, 252–77) gives an account of the life-history, morphology, and systematic position of *Apelma* Kieff and *Thyridomyia* gen. nov. (Ceratopogoninæ).

Other Orders.—A new British shore-dwelling collembolon (*Orchesella littoralis* is described by J. M. Brown (*Ann. Mag. Nat. Hist.*, **16**, 155–60), the known littoral forms of Britain now comprising about a dozen species. H. Womersley (*Entom. Mo. Mag.*, **61**, 250–2) describes two new British Collembola, a new genus *Protanurophorus* being erected with *P. pearmani* sp. nov. G. H. Carpenter (*Manchester Museum*, 1925, Pubn. 89) describes eleven species from southern New Zealand, a new genus, *Plantanurida*, being described. J. R. Denis (*Ann. Soc. Entom.*, France, 94, 261–90) continues his studies on the Collembola of the Paris Museum. Indian Coniopterygidæ (Neuroptera) is the subject of a paper by C. L. Withycombe (*Mem. Dept. Agric.*, India, 1925, *Entom. Ser.*, **9**, No. 1, 1–20), eleven new species being described. Another paper by the same author (*Trans. Entom. Soc.*, London, 1924, 303–411) deals with some aspects of the biology and morphology of the Neuroptera, with special reference to the immature stages and their possible phylogenetic significance.

ARTICLES

THE DETERMINATION OF STELLAR PARALLAX

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An accurate knowledge of the true distances of the stars is of fundamental importance, either directly or indirectly, in many of the problems of modern astronomy. Such knowledge, for example, is requisite before anything can be known about the sizes of the stars, their masses, luminosities, space velocities, and other characteristics which in their turn are of vital importance in the study of stellar physics. In the more cosmical problems relating to the structure, history, and future of the Universe as a whole, individual stellar distances are equally necessary to the formation of any reasonable hypotheses. This importance of stellar distances was realised by astronomers even in olden times, and many attempts were made by them to measure or estimate in various ways the distances of bright stars. These attempts for a long time met with no success, since the quantities to be measured required a precision far beyond that attainable by the instruments which were used. The method employed was the most obvious one of direct triangulation, in the manner of terrestrial surveyors, the main difficulty being to find a base line of sufficient length. It was speedily discovered that no terrestrial base could be of the slightest use in measuring such enormous distances, but with the gradual acceptance of the Copernican theory of the Solar System came the realisation that a base line of more promising dimensions was available in the diameter of the Earth's orbit. During an interval of six months the Earth moves from one point in space to another 186 million miles distant (neglecting the motion of the Solar System as a whole), and the stars might, therefore, be expected to show a sensible parallax when viewed at intervals of six months. The existence of this parallax was, indeed, regarded as the acid test of the Copernican hypothesis, and failure to detect it was regarded by opponents of Copernicus as decisive evidence against the validity of his theories.

Two methods were adopted in the attempt to measure a star's annual parallax (it may be mentioned, in passing, that this term is used with the restricted meaning of half the maximum angular displacement of a star due to the Earth's change of position in six months). The most natural was the absolute method, in which a star's apparent position was measured either with a transit circle (giving the Right Ascension and Declination of the star), or by measuring its zenith distance with a zenith sector. The very large observational and instrumental errors involved in this method made it quite useless for the measurement of such small quantities as stellar parallax, and even with the refinements of modern instruments of precision the method is very inaccurate for the purpose. Such attempts were therefore foredoomed to failure, though it is interesting to note that the great amount of work expended in this manner was by no means wasted, since it led to the important discovery of the aberration of light by Bradley. The other method was based on the assumption that bright stars only appear bright to us on account of their comparative nearness, and stars which appear to us as very faint must be at much greater distances than those which appear bright. Thus, if the position of a bright star is measured relatively to neighbouring very faint stars, the parallaxes of the latter may be regarded as almost negligible (owing to their great distances), and the relative motion of the bright star will give a close approximation to its parallax. This relative motion is measurable with much greater accuracy than is possible with absolute positions, but even so the early attempts in this direction only met with failure. Here again, however, the indefatigable labours of Sir W. Herschel (who originated this method, and attempted to apply it by micrometrical measures of close pairs of stars differing greatly in magnitude) were rewarded by his discovery of binary stars, which compensated for his lack of success in attaining the primary object of his great work.

Success in measuring stellar parallax was not reached until 1838, when, by a curious coincidence, three observers (Bessel, Struve and Henderson) published results of their work more or less simultaneously. Each observer had been working independently of the others, by a different method, and on a different star, and the publication of their results—the first direct measurements of stellar distances—was a remarkable and important occurrence. Bessel, who was probably the first in the field, found a relative parallax of 0"·314 (the value is given in seconds of arc) for the star 61 Cygni by measuring its differential motion relative to certain faint stars with a heliometer. This method, as will be explained later, is probably the most accurate of any visual method, especially in the hands of a skilful observer, and Bessel's result was of much higher accuracy than either of the other two, though the latter were of great value in indicating a probable inner limit to stellar distances and serving to some extent to confirm Bessel's result. Struve used the micrometer method, previously tried by Herschel on double stars. This also is a differential method, but the micrometer is inferior in practice to the heliometer in measurements of this kind, especially if the separation between the stars to be measured is great. Henderson, by the absolute method using a zenith sector, was able to show that the parallax of α Centauri was rather less than one second of arc. This observation is interesting in view of the fact (which has appeared from later observations) that α Centauri is one of our nearest neighbours. The work of these three observers showed, therefore, that the measurement of stellar parallaxes might at last be regarded as a practical proposition, but that it necessitated lengthy and untiring observation, very accurate instruments, and a skilful observer in order to attain to any reasonable accuracy in the measurement of such minute quantities, since their results made it seem probable that no star has a parallax greater than $1''\cdot0$, or, in other words, that no star is nearer to us than about 19 billion miles (giving "billion" its English meaning of a million million).

At this stage it might be well to remark that the very great magnitude of stellar distances makes it inconvenient to express them in miles. In astronomical works they are usually given simply as parallaxes, and rarely in linear dimensions, a proceeding which possesses many advantages both to the practical worker and to the computor, in addition to economising space in printing. It is frequently necessary or desirable, however, to translate the parallaxes into linear distance, and several units have been proposed for this purpose. The "Astronomical Unit" (*i.e.* the mean distance of the Earth from the Sun) has been used, but is very little better than the mile in expressing stellar distances, its chief application being to dimensions within the Solar System. The "siriometer," proposed by Charlier, is equal to 1 million astronomical units, corresponding to a parallax of $0''\cdot206$, and the "siriusweiter" of Seeliger is of similar dimensions. These are more convenient units to use for the purpose, being more comparable with the distances actually found. They have not, however, found favour in general use; possibly because some stars are nearer to us than 1 siriometer, and it is more convenient to have a unit smaller than the distance of the nearest star. The unit which is now generally adopted and has practically superseded all others—at least in technical works—is the "parsec." One parsec is the distance at which a star would have a parallax of 1 second (hence the name). It is, therefore, slightly less than the distance of the nearest star, and is about one-fifth of a siriometer, or about 19 billion miles. It has the advantage of being easily derived from the parallax, since the distance of a star in parsecs is the reciprocal of its parallax (measured in seconds of arc). In popular works on astronomy the unit the "light-year" has had considerable vogue. It is (as the name implies) the distance which would be traversed by a ray of light in one year, moving with the velocity of 186,000 miles per second. This unit is of convenient dimensions, is very expressive, and appeals to the imagination, but it has not received the general support of professional astronomers in place of the more useful parsec.

The work of Bessel, therefore, showed that 61 Cygni, with a parallax of 0″·314, was at a distance of about 3·2 parsecs, or 10 light-years, while α Centauri appeared to be a little more than 1 parsec distant. This initial success was not followed by a very rapid increase in our knowledge of stellar distances, since the determination of individual parallaxes was still a lengthy and laborious operation; but with the gradual improvement of astronomical instruments—especially following the adoption of photography in astronomical work—a more rapid advance has been made. Our knowledge of stellar parallaxes is now much more accurate, though the number of directly measured stars has risen only to about 1,500. The direct measurement of a parallax is still by no means a simple operation, and the more distant a star the greater is the difficulty, since the instrumental and personal errors become greater than the quantity to be measured. For parallaxes of less than 0″·01 the accuracy at present attainable is scarcely sufficient to give more than very approximate values with large probable errors. We are thus limited in the knowledge derivable from direct measurement to the nearer stars (since stars within a radius of 100 parsecs must be considered as comparatively near neighbours); but work is being carried out along these lines in many modern observatories, particularly those of Allegheny, Dearborn, Greenwich, McCormick, Mount Wilson, Sproul, and Yerkes, so that our knowledge of stellar parallax is increasing daily both in accuracy and in numbers.

§

Modern methods of determining stellar parallaxes may be divided for convenience into the two main divisions of fundamental and secondary methods, the latter being those which require a preliminary knowledge of the parallaxes of some standard stars before they can be available for obtaining others. The fundamental division includes, first of all, the trigonometrical method, which has been briefly outlined above and which can be applied in various ways. This trigonometrical method will now be discussed in rather more detail, with especial reference to its modern developments.

Absolute measures of a star's position made either with a meridian circle telescope or a zenith sector are of very little use for determining a star's parallactic displacement, as has already been remarked, and differential measures of a star in relation to faint companions are the basis of all modern methods of parallax work. The results give, of course, only relative parallaxes ; that is to say, the difference between the parallax of the principal star and the mean parallax of the comparison stars. The latter are chosen from among those stars which are very faint (without being too faint for accurate measurement) and which show little or no appreciable proper motion. If the choice is suitably made, the mean parallax of these stars is very small and can be approximately estimated. This mean parallax must be added to the relative parallax of the principal star in order to reduce the latter to its absolute value. It frequently occurs that negative parallaxes are obtained from differential measures of this kind, though a negative parallax is theoretically an absurdity. The apparent anomaly is due in such cases to the fact that the principal star is more distant than the comparison stars, or to a combination of this cause with instrumental and observational errors. In order to eliminate the effect of proper motion—that is, the apparent movement of a star due to the motion of the solar system as a whole, combined with the star's own "peculiar" motion—it is necessary to make observations on at least three different occasions separated by intervals of six months. In the third of these observations (which will be one year after the first), the parallactic effect will be zero and any displacement of the star will be due to proper motion. Having determined this motion, a correction can be applied to the results obtained from the second observation in order to deduce the parallax.

The measures may be made by a variety of instruments. The transit instrument, for example, by giving the exact moment of time at which the stars cross the observer's meridian, may be used to determine differences of Right Ascension between the principal star and its companions. If this difference is observed regularly throughout the year the effect of a star's parallax on its apparent Right Ascension can be extracted. From this parallax in Right Ascension it is comparatively simple to compute the true annual parallax. The method is one, however, which presents great practical difficulties, although it has been used with a certain amount of success by Kapteyn, Flint, and others. Flint in particular devoted a considerable amount of time to the problem of eliminating as far as possible the errors inherent in the method and brought every possible refinement to bear in the use of his instrument for this purpose; but in spite of his skill as an observer and his special experience in this particular work, Flint's results cannot be compared in accuracy with those obtained by other methods. They are now only used with caution, together with others obtained from meridian observations, and the method is very little used for parallax work.

Two other instruments are available for visual observations—the micrometer and the heliometer. The former consists essentially of two spider threads movable by means of a graduated micrometer screw and placed in the focal plane of the telescope objective, so as to be visible simultaneously with the star images. These threads are moved by the thumb-screw until each of the images of two stars whose separation is to be determined is bisected by a thread, when the separation (given by the micrometer scale) may be reduced to angular measure by a simple calculation. This operation is far from being as simple as it might appear to the uninitiated; and requires, indeed, very great skill and experience to be performed accurately. The telescope is not rigid, and the bisection of a star's image is only of momentary duration, while the stars (unless very close) must be observed alternately by the operator. The micrometer is of very great use in double-star astronomy, where the separations to be measured are very small, but with the greater separations usually required in parallax work it becomes unreliable and inaccurate and has now been discarded for this purpose.

By far the most accurate instrument for visual purposes is the heliometer. It was the instrument used by Bessel in his observations of 61 Cygni, and has since been used with conspicuous success by other observers, notably the late Sir D. Gill and W. L. Elkin. In this instrument the object-glass of the telescope is divided diametrically into two halves, one of which can be moved relatively to the other in a direction parallel to the dividing diameter. The object-glass can also be rotated as a whole round the optical axis of the telescope. When the two halves of the objective are in juxtaposition, the telescope functions normally; but if they are relatively displaced, two separate images of each star are formed (one by each portion of the objective), and objects will appear duplicated to the observer. One of these images will be fixed and the other movable, the separation between them depending on the distance through which the movable portion of the object-glass has been moved.

An observation is made by first rotating the object-glass until the dividing line is parallel to the line joining the two stars, and then adjusting the movable half until one star appears superimposed on the other (the movable image of one star being brought into coincidence with the fixed image of the other). It is evident that such an observation is more easily and accurately made than that required by the micrometer. Any slight motion of the telescope will move both star images equally and will not affect their coincidence, whereas in the micrometer a star appears to be continually oscillating to either side of the dividing wire and the estimation of bisection has to be made rapidly. Moreover, with the latter instrument two pairs of objects must be observed, as nearly simultaneously as possible, while with the heliometer only one coincidence has to be noted. The heliometer therefore, in capable hands, is the best instrument that has yet been devised for visual observations of a star's parallax, and the results obtainable with it are only slightly inferior to those given by the photographic plate.

The introduction of photography was the starting-point of a rapid and striking development in almost every department of astronomy, including that of stellar parallax, to which photography was first applied by Pritchard in 1892. The labour of observation was greatly reduced, while the accuracy of the method now exceeds even that of the heliometer. It is evident that if a photograph be taken of a star, together with the surrounding field, the plate may be examined at leisure. The distance from the central star of as many stars as are required may be measured under a microscope, and these measures may be checked at any future date by repetition, whereas visual observations, once made, stand on their own merits and cannot be tested afterwards. In actual practice, however, the method is more complicated than it appears at first sight—as is usually the case in astronomical observation—and the work involves numerous practical difficulties. To quote Sir D. Gill, " . . . every preconceived source of possible error has turned out to be a reality," and these " preconceived sources " are by no means few in number. One of the most important is that known as the guiding error. It is difficult, if not impossible, to guide the telescope so accurately that the stellar images remain at exactly the same spot on the photographic plate throughout the exposure, and any slight excursion of these images from their mean position will tend to produce an elongated impression on the plate instead of one truly circular. Hence difficulties and errors will be introduced in the measurements. This elongation, moreover, depends on the magnitudes of the stars photographed, since for a very faint star the light may not be sufficiently powerful to leave any appreciable impress on the plate during the brief excursions from the normal position, while for bright stars the effect will be strongly marked. Thus the principal star, which is of necessity brighter than the comparisons, will show a relative spurious displacement, and so give rise to serious error. The length of exposure will naturally affect the amount of this displacement, so that telescopes with large apertures possess a great advantage over smaller instruments in the shorter exposures which they require ; but even when the exposure is reduced to a minimum and the guiding made as mechanically perfect as possible, the effect is still noticeable. The difficulty has been overcome by artificially reducing the brightness of the central star, while leaving the others unaffected, thus greatly reducing the elongation as well as equalising it for all the stars concerned. This artificial reduction has been performed in several ways. Russell used a piece of glass, so placed that the light from the stars had to pass through it before reaching the photographic plate. On this was a small spot of yellow stain, and the glass was so adjusted that the stain just covered the image of the central star, whose light was thus rendered equal to that of the comparison stars before being photographed. Other observers have used screens of different types, but the method now generally adopted is to use, in place of a screen, a small rotating shutter, consisting of a disk in which is an adjustable sector-shaped opening. By rapidly revolving this shutter in front of the central star and adjusting the opening to suitable dimensions, the magnitude of the star may be reduced to any desired value. The fact that the opening is cut in the form of a sector of the disk causes the percentage reduction of the star's light to be the same at whatever speed the disk may be rotated or at whatever distance the star's image may be from the centre of the disk.

In addition to the above precaution, which has been explained at some length on account of its vital importance, there are other general rules to be observed in order to eliminate as many sources of error as possible. For example, the comparison stars should be as symmetrically placed with respect to the central star as possible, the photographs should be taken when the star is as near as is practicable to the meridian, and the photographs at different epochs should be taken under conditions (both instrumental and atmospheric) which are as similar as possible. In practice, three or four plates are usually taken at each of the three epochs in order to obtain the best possible results. These plates are measured under a measuring microscope, the rectangular plate co-ordinates of the stars having to be reduced to Right Ascension and Declination by a simple formula. The differential displacement of the principal star must then be corrected for proper motion of the stars, aberration, instrumental errors, and other factors; and finally, the relative parallax may be reduced, as previously explained, to its absolute value. The correction to reduce to absolute parallax depends mainly on the magnitude of the comparison stars. For most of the modern instruments engaged in this work it amounts to 0″·004 or 0″·005, but for the great 100-inch telescope of the Mount Wilson Observatory (which is able to use fainter stars) the correction is probably nearer to 0″·002.

On account of its great advantages over visual methods, especially in the reduction of the labour involved, together with the greater rapidity and accuracy of results obtainable, the photographic method is the only one used extensively for direct determinations of stellar parallax at the present time. It is, however, limited in its scope to comparatively near stars. For parallaxes smaller than 0″·010 the probable errors become equal to or greater than the parallaxes themselves, while for still smaller parallaxes the results are practically valueless individually, though they may still be of some use in giving the mean distance of a group of stars whose parallaxes have been observed in this way. Fortunately, there is another fundamental method of determining stellar distances which, although indirect and based on an assumption that may occasionally be unjustified for individual stars, is nevertheless a very valuable means of increasing our knowledge of stellar parallax. It is founded on the theory of "moving clusters," the fundamental data required being measurements of stellar motions.

The observation of a proper motion is one subject to far less uncertainty than that of a parallax. The amount to be determined is cumulative instead of being periodic, so that the accuracy with which proper motions are known increases with time, and there is now a considerable body of accurate knowledge of such motions. Now, it has been noticed that in certain regions of the sky the proper motions of a number of stars appear to converge towards a definite point on the celestial sphere, and to be approximately equal in amount for the individual stars concerned. This at once suggests the idea that these stars are moving together in a group, the apparent convergence being the effect of perspective. Each star, according to this hypothesis, is moving with equal velocity and in a parallel path to those of its companions, the whole group being an independent "moving cluster" not related in any way to the neighbouring stars which do not share in its motion. If only two or three stars show this similarity of motion, the effect might be attributed to coincidence, but this can scarcely be the case when a considerable number of stars is involved; in fact the moving-cluster hypothesis becomes the only possible explanation in many cases, such as the Taurus cluster, discovered by Boss. For this group it has been shown that if we assign to it a reasonable age, judging from the spectral types of the stars, then the individual velocities must agree to within a small fraction of a kilometre per second in order that the stars should remain a compact group as observed. The hypothesis is further strengthened by the fact that the stars nearer to the point of convergence show smaller apparent velocities than those farther away, as would be expected from the foreshortening. If, then, we may assume that the stars are moving as described, some important results follow. All that is required is the radial velocity of at least one of the stars in order to give us the parallaxes of all. This radial velocity is of course determined in linear measure (kilometres per second), which we can resolve along the known direction of motion (obtained from the known convergent point), thus giving us the true linear velocity of the star and hence of every star in the group. From this known total velocity of any star it is an easy step to calculate the velocity transverse to the line of sight ; but this is the proper motion of the star, which is already known in angular measure, so that the distance of any star in the group may be obtained. The greater the number of radial velocities which are known, the greater is the accuracy of the results, and in cases of well-authenticated moving clusters this is one of the most accurate methods which is available for determining stellar parallaxes. It is of course possible that an individual star, by reason of a coincidence in its apparent motion, may erroneously be included in the cluster ; but such a case can frequently be detected from dissimilarities of the star in other respects (such as spectral type) or from the absurdity of the resulting parallax.

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So far we have considered methods which are fundamental, in the sense that the results are derived directly or indirectly from observed data without any knowledge or assumption with regard to the distances of any other stars. The number of parallaxes which can be measured by these methods is, as has been pointed out, very limited ; but the information thus obtained can fortunately be used as the foundation of other methods by means of which our knowledge of stellar distances can be largely increased.

The first of these secondary methods to be considered is one devised by Adams and his colleagues at the Mount Wilson

Observatory, known as the spectroscopic method. It rests on the fact that a star's apparent magnitude does not of itself give any indication of its absolute, or true, magnitude, since a very bright star if at a great distance will appear to be very faint and *vice versa.* A knowledge of a star's distance, therefore, combined with its apparent magnitude, is required in order to give its absolute magnitude; conversely a knowledge of both the absolute and apparent magnitude will give the star's distance. Now, the causes which affect a star's absolute brightness—such as size, mass, temperature, and state of ionisation of the elements in its atmosphere—might be expected to affect their spectrum, and this is exactly what Adams found. The absolute magnitudes of stars which are at the same temperature are intimately connected with the degree of ionisation of their elements. Thus a "giant" star of type G for example, although at approximately the same temperature as a "dwarf" star of the same spectral type, may be several magnitudes brighter (absolutely) than the latter. It is enormously greater in volume (the density being correspondingly small) and the ionisation in its atmosphere is more complete than in the dwarf star; hence the ionised lines of some elements will be stronger in the spectrum of the brighter star. By examining stars of known absolute magnitude Adams was able to demonstrate and give a quantitative value to this relation between the intensity of certain ionised lines and the absolute magnitude of the star in which they originated. He made eye estimations of the intensities of suitable lines (such, for example, as the Sr^+ line at λ 4216) on an arbitrary scale, in which the faintest line visible was given the intensity 1 and the strongest was called 12. These estimations were made in the spectra of stars whose parallaxes (and hence absolute magnitudes) were known; so that he was able to plot the estimated intensities against absolute magnitude in order to obtain a curve expressing the relation between the two. This curve, once established, could be used for other stars. Thus the intensity of the necessary line was observed in the spectrum of a star, and reference to the curve gave the star's absolute magnitude from which the distance or parallax could at once be derived. Each suitable line in the spectrum gave an independent value of the parallax, while these determinations were multiplied again by the number of photographs available. Finally, the mean of all the results thus obtained gave an accurate value of the star's parallax.

It is evident that the intensity of a line as observed in the photographed spectrum of a star will vary greatly according to the length of exposure, treatment in developing, and other conditions, so that absolute measures of individual intensities are useless. Every line will, however, be nearly equally affected, at least within a small range of wave-length, and in practice the intensity of a variable line is measured relatively to a neighbouring standard line which does not change with absolute magnitude. This difference of intensity will be unaffected by the above conditions and is the quantity actually correlated with absolute magnitude in the standard curves. Another possible source of error lies in the fact that all the spectral lines vary in intensity with spectral type, and in order to eliminate this effect the standard reduction curves must be made separately for each type of stellar spectrum.

The advantages of the spectroscopic method are obvious. When once the standard curves are established, all that is necessary for the determination of a star's distance is a single photograph of its spectrum, so that parallaxes may be obtained very much more rapidly than with the trigonometrical methods which require an interval of at least six months. With regard to accuracy, this does not depend (as in the other methods) on the distance itself. Provided a distant star is bright enough to be photographed, its parallax may be obtained with the same percentage error as a near star. For stars of very small parallax this means that the actual error is correspondingly small, and the method will therefore be more accurate than the trigonometrical method, though for near stars the latter is the more accurate. The accuracy depends, first of all, on that of the standard curves—that is, on that of the original parallaxes on which the method is founded. It also depends on the accuracy with which the estimations of line intensity are made, and on the possible influence of unknown causes on the line intensities themselves. It has been shown that the reduction curves are only strictly applicable to stars whose mass is the same as the mean mass of the original standard stars. If a star's mass differs from this mean value, there will be a slight error in the deduced parallax, though the amount of the error is not very great.

Adams' spectroscopic method has been used, with slight modifications, by several other observatories. The modifications are mainly in the manner of measuring the line intensities, which were originally estimated by comparison with standard spectra. At the Norman Lockyer Observatory a wedge of neutral-tinted glass is in use, designed by the Director, Dr. W. J. S. Lockyer. This is moved slowly over the spectrum until the line under observation just disappears, when the position of the wedge gives a measure of the line's intensity. A preliminary investigation by the writer showed the value of this wedge for parallax work and the possibility of obtaining the necessary reduction curves by its aid. It has since been used by Rimmer in the measurement of more than a thousand parallaxes. At the Victoria Observatory, Harper and Young have adopted a different method in which is used a comparison scale of artificial lines formed by photographing fine wires with varying exposures. They have recently published a list of 1,105 spectroscopic parallaxes based on line intensities estimated in this way. Among other observatories undertaking this type of work may be mentioned Harvard, Arcetri, and Stonyhurst.

The method as outlined above is only applicable to stars in which the enhanced metallic lines are sufficiently prominent. In other words it is limited to stars of types F, G, K, and M. The A-type stars show few lines in their spectra suitable for the purpose, and have been treated by Adams in a different manner. He found that spectra of type A could be divided into two classes, according to the sharpness or diffuseness of their lines. An examination of their absolute magnitudes showed that stars with sharp spectral lines were brighter than the other class, the difference being, on an average, about half a magnitude. A further relation was found between the subdivision of spectral type and absolute magnitude, a systematic decrease in luminosity being evident in proceeding from A0 stars down to A9. Therefore, by carefully classifying these stars, both as regards the character of their lines and the subdivision of their type, he was enabled to obtain their absolute magnitudes, and hence their parallaxes. The method is open to some criticism, and is probably not so accurate as the method for stars of later type; but considering our present scarcity of knowledge regarding stellar distances, any information is valuable, and this method is at least of use in giving mean parallaxes of groups of stars as well as approximate values of individual parallaxes.

The B-type stars possess the further disadvantage of being so remote that trigonometrical parallaxes are both scarce and inaccurate; in consequence of which there is little information available upon which to found a spectroscopic method. There are, however, some moving clusters of B-type stars; and parallaxes from these sources, together with such trigonometrical parallaxes as were available, were utilised by the writer in an attempt to extend Adams' original method to these stars. A relation was obtained between absolute magnitude and the intensities of helium lines of the $1P - mD$ series, which gave curves suitable for obtaining further parallaxes. The variation of these lines, however, with spectral type, and the nature of the standard parallaxes which were available, render the results of less accuracy than those for metallic line stars. Nearly simultaneously with this investigation, a list of parallaxes of B-type stars was published by Adams, using the method previously adopted by him for A-type stars, and based on material similar to that used by the writer. A third method has been proposed by Lindblad for stars of types A and B in which he correlates the difference of density of the continuous spectrum on either side of λ3907 with the absolute magnitude of the star. From this relation he claims to deduce luminosities with a probable error of less than half a magnitude. Owing to the great distance of the B-type stars, the probable errors of spectroscopic parallaxes are presumably numerically small; and although not of the same accuracy as the results for later types, they represent probably the best information at present available for these stars, apart from group-motion parallaxes.

The second method to be considered in the general class of secondary methods is the important one known as the " dynamical " or " hypothetical " method. The former term is preferable, since any indirect method resting on hypothesis—such as the moving-cluster method—may be (and has been) called " hypothetical." The dynamical method depends on the fact that from the known orbital elements of a binary star (obtained from visual observations) the linear dimensions of the orbit can be calculated if the combined mass of the two stars is known. Since the angular dimensions are known, the distance is at once determined by elementary trigonometry. In other words, a known relation exists between the total mass of a binary system and its parallax. Now, our knowledge of stellar masses gives strong evidence in favour of the assumption that there is only a limited range of such masses, and values outside that range are extremely rare. Consequently we may assume the total mass of a binary system to be twice the average stellar mass without very serious error, and thus we can determine the distance of the system. This average mass is only known through previous observations of parallax, and hence the method must be classed as secondary. Fortunately, an error in the assumed mass only gives rise to a much smaller proportional error in the resulting parallax, and the method is very valuable in augmenting our knowledge of the distances of binary stars. It has been used by Russell, Shapley, and others, but more extensively by Jackson and Furner, who have recently published valuable lists of dynamical parallaxes. They have also shown that observations over a complete period of revolution are not necessary, many of their published results being based on only partially observed orbits.

One other method may be mentioned in this section for the sake of completeness, since, although of no value for use in our own galactic system, it affords valuable information concerning the distances of globular clusters and other groups of stars. It has been shown by Miss Leavitt, and later by Shapley, that the Cepheid variables found in the Magellanic cloud and in globular clusters show a well-marked correlation between the periods of their variation and their mean apparent magnitudes. These clusters are so remote that the stars in any one cluster may be regarded as at approximately equal distances. It follows, therefore, that a relation exists between period of variation and absolute magnitude of the Cepheids, the exact form of this relation being determined by Shapley from the parallactic motions (see the following section of this article) of nearer Cepheids. Although Shapley's method of deducing the necessary numerical factors in this relation may be open to criticism, there is no doubt that the relation does exist; and independent tests of Shapley's results seem to indicate that they are not widely in error. It is possible, therefore, from the period of a Cepheid variable to deduce its absolute magnitude, and hence its parallax.

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The methods hitherto examined are all applicable, directly or indirectly, to individual stars. They are, however, limited in their use by instrumental imperfections, or by restriction to certain stars or groups of stars; consequently when all the results at present available from these methods are collected, they may be insufficient for the purposes of many astronomical problems. Now, it frequently happens, especially in statistical studies, that individual parallaxes are not of vital importance, and may be replaced by the mean parallax of a group of stars. It is therefore useful to be able to supplement our knowledge by a determination of such mean distances, which may be done in several ways. The most important method, and the one of most general application, is that of parallactic motion. It has been found, from a study of stellar radial velocities and proper motions, that the Solar System is travelling through space (*i.e.* relatively to the "mean of the stars") with a velocity of about 20 kilometres per second. A base line for the trigonometrical method is therefore at once suggested in the distance traversed by the Solar System in a definite interval of time, and the apparent displacement of stars due to such a large movement of the Earth should give accurate parallaxes. The difficulty of the method lies in the fact that it is impossible to separate this parallactic displacement of a star from its own peculiar motion, both of which are combined in its apparent or proper motion. The method is thus useless for individual stars; but if we take a number of stars together, we might assume that their individual peculiar motions are distributed at random and, if the average were taken, would cancel one another. In such a group of stars if the mean observed proper motion differs from zero, the difference should be due entirely to parallactic motion, so that the mean distance of the group may be found. The method may be applied in two ways. The proper motion of a star may be resolved into two components, one parallel to the Sun's motion through space, the other at right angles to this, and either component may be used independently. It will be noticed that the whole of the parallactic motion is included in the former component, which gives a solution for the mean parallax without any additional information. In the case of the transverse component the apparent motion is unaffected by the solar motion, and a knowledge of radial velocities is required in order to complete the solution. Certain precautions have to be borne in mind when applying this method. For example, a sufficiently large number of stars should be chosen, to ensure as far as possible the random nature of their individual motions, but there should not be a wide range of distance among the stars in any group. A systematic error will of course be introduced if the group possesses any residual motion as a whole, such as in a moving cluster.

Among other methods of determining mean parallaxes may be mentioned that of Kapteyn and Van Rhijn, who derived a formula giving mean parallaxes of groups from their mean proper motions and apparent magnitudes. It must be remarked that this formula is only strictly applicable to stars whose distances are already known by some other method, since the data necessary to apply the formula to any particular case have been used previously to arrive at the formula itself. The formula is therefore little more than a convenient way of expressing, or perhaps regrouping, what is already known. Again, the fact may be mentioned that the average luminosities of " dwarf " stars vary according to their spectral types, the earlier-type stars being brighter than the others. If then we have a group of stars of the same spectral type, we may assume a certain mean luminosity and hence deduce its mean distance. Finally, attention may be called to the fact, already pointed out, that measured parallaxes, when too inaccurate to be of value individually, may be grouped together and the mean parallax used.

It would be out of place in this article to give any account of the results which have been obtained by the various methods of parallax determination outlined above, or of the facts and theories regarding the construction of the universe to which we are led by a knowledge of such results. The aim has been to describe the principal methods by means of which this knowledge has been obtained by astronomers, together with the difficulties inherent in their application and the relative trustworthiness of their results. It may, however, be remarked in conclusion that our knowledge of stellar distances is still far from complete. More observations are required, especially of fundamental parallaxes, both on their own account as well as to improve the accuracy of secondary methods and to enable further methods of this nature to be founded. Such parallaxes are being determined regularly at the great observatories mentioned in this article ; but progress is necessarily slow and it will probably be some considerable time before any further striking advance is made in this, one of the most difficult, as well as one of the most important, of the problems of Astronomy.

THE PASSAGE OF ELECTRICITY THROUGH DISCHARGE TUBES AT LOW PRESSURES

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THE passage of electricity through gases at low pressure has been the subject of much experiment and theoretical speculation ever since the discovery of the vacuum tube in the last century. The phenomena are extremely complicated, and only partial qualitative explanations can in many instances be given, but recent work has not only brought out new and interesting facts, but has also led to the suggestion of possible new methods of explanation. Much yet remains to be done, and the present article has as its object a résumé of well-established knowledge, and an account of some of the more recent experimental observations.

The facts are briefly these. If a long glass tube furnished with two metal electrodes fused through its walls be connected to a vacuum pump and the air gradually withdrawn, beautiful, coloured, glow effects are observed within the tube when a potential of a few hundred volts is applied to the electrodes. The appearance is very variable, depending on the pressure, the nature of the gas, the disposition of the electrodes, the potential applied, and so forth.

For a given applied potential the current does not commence to flow through the tube until the gas pressure falls to a certain value, when it suddenly appears, increases to a maximum as the gas pressure is reduced, and finally, when all but a few molecules of gas are removed, ceases again to flow.

In the light of our modern views we suppose that the current in the tube is carried in part by the very mobile electrons (torn out by ionisation mainly from the atoms) which move up towards the anode, and in part by the more sluggish positive ions of the gas which move up to the cathode.

When once the current is started—and this matter will receive a little more attention later—it is maintained by the production of fresh ions and electrons, providing that the potential applied to the tube electrodes is sufficiently great.

While most of the current will be carried by negative electrons and the complementary positive ions, there will be always a few negative ions present in the tube produced by the attachment of an electron or electrons to neutral atoms or molecules.

The manner in which electrons are removed from atoms is not yet well understood, but our views have taken form somewhat definitely during the last decade or so, experimental research in the matter having been guided recently to a considerable extent by the valuable picture of the atom adopted by Rutherford and elaborated by Bohr and his followers.

In this model it is suggested that the neutral atom consists of a central positive charge of minute size, round which electrons are grouped in various levels in sufficient number to balance exactly the central charge. Dynamic stability must be conferred on these electrons, and it is imagined that this may be attained by their motion in closed orbits round the nucleus.

Each electron will thus have a certain " binding energy " proper to its orbit or level.

In the usual discharge-tube operating at comparatively low potentials it will ordinarily be possible only to ionise the atoms by removing electrons from the outer atomic levels. This may be one of the results of electron impact.

Another possibility would be the imparting of sufficient energy to an electron in one atomic level to raise it to another level, having an electron vacancy nearer the outside, which operation, while not resulting in ionisation, may produce—when the electron returns to its old position—radiation, either luminous or non-luminous.

It is now supposed that both of these operations—ionisation and radiation—may sometimes take place gradually, that is, if the energy of the bombarding electron is insufficient, the atom may store up the energy until another electron or yet another arrives making up the total required. Ordinarily, however, this cumulative effect will not need to be taken into account.

There is still another way for the present purpose, in which the bombarding electron may part with its energy. It may convert it, mechanically perhaps, into atomic energy of translation, that is to say, it may raise the temperature of the gas in the tube.

Leaving this matter of radiation and ionisation for the time being, it is convenient to consider now the factors which determine the energy possessed by the bombarding electron.

There is a well-known formula $\frac{1}{2}mv^2 = eV$ connecting the kinetic energy of a freely moving charged body of mass m and charge e, initially at rest, but allowed to move in an electric field between two points differing in potential by V.

It is the energy eV acquired during the motion of the electron in the tube which enables it to perform the functions just outlined.

In most cases it is difficult to say precisely what V may be; partly because the particular electron singled out for consideration is not the only one in the tube, so that in addition to the potential applied to the electrodes there are also other potentials due to the other electrons and ions present—the so-called space charges. These complications are often too involved to yield to mathematical treatment. When the gas pressure is reduced so low, however, that the mean free path of the electrons becomes considerable, the kinetic energy of the electrons becomes—for moderate potentials—equal to the product eV.

It was with an apparatus working under conditions of this sort that J. J. Thomson in England, and independently at the same time Kaufmann and Wiechert, made the original determinations not only of the velocity of the cathode rays but also, by magnetic and electric deflexions, the important ratio e/m.

The method consists briefly in causing the electrons to pass through a fine aperture, and thereafter between a parallel pair of plates maintaining a known electric field, at right angles to their path. The resulting deflexion was observed on a fluorescent screen. Magnetic deflexion was also produced, and from the two readings the ratio e/m was calculated.

It is of interest to observe in this connection that in these experiments it has been usual to employ potentials (V) of many thousands of volts, using the ordinary type of cold cathode. Under such conditions the electrons, when V is steady, apparently all have the same speed.[1]

The mechanism of the production of the discharge in a highly evacuated tube as Thomson used is understandable in the light of an experiment due to Villard (1899).

This investigator showed that an opaque obstacle placed in front of the cathode stopped the emission of electrons from that part of the cathode immediately in front of it. It was as if something came up to the cathode from the part of the

[1] Experiments carried out recently in Leeds, using a hot cathode and V only about 100 volts, have shown that the electrons which pass through an aperture do *not* all possess the same speed.

When the beam is deflected by a magnetic field it appears that comparatively few of the electrons have the maximum energy corresponding to eV, but there is a magnetic spectrum often of quite a complex character, showing very clearly that there are groups of electrons having energies less than this maximum possible by definite amounts.

It seems probable that the electrons impinging on the edges of the aperture are "reflected" with definite energy losses corresponding possibly to the ionisation or radiation potentials of the material of the aperture.

These losses, however, are only of the order of a few volts, and would not have been observable with V comparatively great.

tube shielded by the obstacle, and it was this something which caused the emission of electrons.

It was immediately suggested that positive ions coming up to and striking the cathode liberated electrons therefrom. Goldstein soon after showed that if a perforated cathode were used then positive ions moving at a high speed actually streamed out behind the cathode. These are the positive rays investigated with such important results by J. J. Thomson, Wien, Aston, and others.

The conclusion is therefore that electrons and positive ions are interdependent, the former being liberated from the cathode by the latter. Once the discharge is started, therefore, the supply is maintained by virtue of the high speeds produced by the applied potential.

It is clear that on this view it should not be possible to pass a current through a tube in which the vacuum is perfect. This is the case so long as ordinary cold electrodes are employed.

Nevertheless, the so-called "pure electron" current can be made to pass if the cathode is heated in some way to a sufficiently high temperature to cause thermionic emission of electrons from its surface. It will not be out of place to consider this type of vacuum tube in rather more detail at this stage, since such considerations will bring out a point of very great importance, the influence of the "space charge."

Following up the discovery of the Edison effect relating to the emission of electricity from the limbs of electric lamp filaments in vacuo, many investigators have examined this emission under widely varying conditions of experiment.

It has now been definitely established that even in as perfect a vacuum as it is possible to obtain electrons may come off from the surface of any heated substance. Their escape is assisted by the application of an electric field in the right direction and by raising the temperature.

The well-known law of Richardson states that the saturation current $i = a\sqrt{T} . e^{-b/T}$, where T = the absolute temperature of the cathode, a and b are constants depending on the material of the cathode. Of the theoretical significance of this law nothing will be said here.

It is important to notice that the space between cathode and anode is, in this case, free of positive ions or gas molecules.

To fix ideas for the moment, suppose that the two electrodes considered are plane, of infinite extent, parallel and distant d apart. The current i is the saturation value—as many electrons reach the anode per second as leave the cathode per second.

It is an experimental fact that a rise in temperature—keeping the potential V constant—only increases the current to a certain saturation value. The temperature of the cathode having reached this point, the only ways of increasing the current are to increase V or to reduce *d*.

The reason for this was made clear by Langmuir, who pointed out that when such large currents were employed the electrons just leaving the cathode were under two opposing forces: the first due to the applied potential V, and the second due to the reverse field set up by the electrons in the space between the electrodes—the space charge.

It can easily be shown that on this view the relation

$$i = \frac{\sqrt{2}}{9\pi d^2} \cdot \sqrt{\frac{e}{m}} \cdot V^{3/2}$$

must be true if T has been raised to such a degree that i has reached its greatest value.

The truth of the formula, and therefore of the space-charge hypothesis on which it rests, has been abundantly verified.

It will be seen from the equation that it is possible to base on it a method of determining the fundamental ratio e/m for the electrons emitted from a hot surface.

In all discharge-tubes in which there are appreciable quantities of gas, the space charges play an important part, but it must be remembered that the electron space-charge effect may under certain conditions be considerably modified by the presence of positive ions. The presence of only a few ions in a cloud of negative electrons may reduce their effect enormously on account of the great difference in speed between them.

It has been estimated, for example, that a single ion of nitrogen will neutralise the space-charge effect of many hundred electrons.

For this reason the electron emission from a hot cathode may be very much increased by introducing gas into the tube, which when ionised will largely neutralise the negative space-charge previously limiting the flow of electrons from the cathode.

Having thus briefly dealt with the phenomena in discharge tubes in which very little or no gas molecules are present, the more complicated cases may now be considered in which appreciable quantities of gas enter into the question.

THE APPEARANCE OF THE DISCHARGE

The upper part of Fig. 1 shows diagrammatically the appearance of a glowing tube with cold electrodes. The gas pressure here is in the neighbourhood of a millimetre of mercury and the applied potential a few hundred volts. The position of the various parts of the discharge, viz. cathode glow, Crookes' dark space, negative glow, Faraday dark space, positive column, are there indicated.

The relative sizes of these parts of the visible discharge depend, in a great measure, on the gas pressure. At greater pressures, for example, the Crookes' dark space shrinks until hardly distinguishable as such; at lower pressures it increases at the expense of the positive column, which finally disappears entirely. If the pressure is reduced until the dark-space boundary reaches the anode the discharge abruptly stops and cannot be restarted until either the gas pressure is raised again or the distance between the electrodes increased.

The spectrum emitted by the discharge is, speaking generally, characteristic of the gas within the tube.

THE ELECTRIC FORCE IN THE DISCHARGE

It is important to know the distribution of electric field along the discharge, for from what has been said in a previous paragraph about space charges, inferences can then be drawn as to the mechanism of the discharge and the manner in which electric charges are distributed within the glowing tube.

An obvious method, but one which is open to serious criticism, is to introduce into the discharge metal probes a known distance apart, and by connecting them to some type of electrometer to measure the potential difference acquired. From observations of this sort the electric force can readily be calculated.

The real objection to measurements made on this plan is that such probes will be affected not only by the electric field but also by the free charges present. Electrons and ions—particularly the former—will diffuse to the probes and vitiate the results.

A method more free from blame in this respect is to make use of glowing probes, adjusting their potential until no thermionic emission occurs, when the potential applied must be equal to that which it is desired to measure. Another very good method is to fire a beam of fast electrons of known speed from a subsidiary cathode in a side-tube across the region investigated. These electrons will be deflected, and from this the field in the region through which they have passed can be calculated.

One of the most striking features of the electric field curve in Fig. 1 is the high value of the force in the Crookes' dark space and its greater value nearer the cathode. This is doubtless to be ascribed to the considerable number of free ions in this region. These ions must arise, in the main, in the edge of the negative glow, and move comparatively slowly towards the cathode, constituting a positive space charge. An electron nearer the cathode therefore obviously finds itself in a field of much greater intensity than an electron nearer the negative glow.

But it will be noticed that very near the cathode the field becomes smaller again. This is in the region where the electrons are being set free from the electrode surface, and have not yet reached their full velocity in streaming away as cathode rays. There will thus be a negative space charge extremely close to the cathode which would account for the smaller value of the electric field there.[1]

The fact that in the Crookes' dark space there is only a very faint luminosity (although it is quite certain that there is a copious supply of gaseous ions) may be explained on the supposition that the electric force obtaining there is high enough to prevent recombination of ions and electrons, by imparting a very high relative velocity immediately after their production. The edge of the negative glow, however, will represent the region at which the electric field by space-charge action has fallen to a sufficiently low value to permit of adhesion and recombination and therefore light emission.

Remembering that the ions and electrons in question are to be regarded as having been produced by the cathode rays, it is now easy to see that the negative glow should extend as far as the " range " of the cathode rays in the gas within the tube. The Faraday dark space thus begins at that point where the cathode rays have spent all their energy in ionisation.

Further, the fact that the electric field in the negative glow has a nearly constant and low value receives a ready qualitative explanation. For in this region there is no separation, on the whole, of the positive ions and their complementary electrons, since, on the supposition just introduced, recombination has been rendered probable with consequent radiation and possibly still more ionisation. The negative glow has therefore the attributes of a good conductor of electricity because of the ample supplies of positive and negative electricity in equal amounts (the ionising cathode rays themselves are, comparatively speaking, small in number). The electric field in such a good conducting region must of necessity be approximately uniform.

On the view which has been suggested it can be seen in a general way that the anode side of the negative glow acts as a kind of phantom cathode, in that it may furnish a supply of slow-moving electrons which must move towards the anode. The electric force is much smaller in this part of the tube than near the cathode, so that these electrons never attain so high a speed as the cathode rays themselves. When they attain ionising speed, however, the positive column begins, and this region, like the negative glow, is, in pure gases at any rate, characterised by a low and sensibly constant electric field.

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[1] It was only very recently that Brose discovered this drop in field close to the cathode. Aston's cathode ray method is inapplicable here, probes are equally useless—but the most ingenious method of observing the Stark effect in the spectrum emitted from this very faintly luminous part of the discharge gave the information desired. The shift of the spectral lines due to the electric field was small, but measurable. A similar result using tubes of a special type is recorded by Foster (*Nature*, Feb. 6, 1926).

With this general—and incomplete—account of matters, it is desirable to return to further and more detailed consideration of the phenomena at the cathode.

CATHODE PHENOMENA

(*a*) *The Starting of the Discharge.*—With a very special arrangement of the discharge-tube it may be shown experimentally that, under the right conditions, quite a considerable delay may occur between applying a potential to the tube electrodes and the appearance of the discharge. This delay can be reduced to an indefinitely small time—in fact, the discharge may be started by bringing radium or any other ionising agent near the tube. This suggests that ions must be present in the tube to commence the discharge—an obviously reasonable hypothesis, since the so-called " natural ionisation " in the air, due to some all-pervading or ultra radiation, may be invoked in aid of the explanation.

The experiment can be conveniently carried out by applying a steady potential from an accumulator of small cells to the tube electrodes, one of which is so arranged as to be capable of motion down the tube. Suppose the anode to be so devised and to be moved towards the cathode. Nothing beyond successive disappearance of positive column, Faraday dark space, and negative glow will happen until the anode finds itself just within the Crookes' dark space. At this point the current suddenly ceases.

The anode may then be moved back a millimetre or so and left there. Still nothing happens perhaps for a few seconds, perhaps for a few minutes—but eventually the current will suddenly flow again, the only parts visible being a small section of the negative glow, and the faintly luminous interior of the dark space. This delay in starting cannot be obtained if a strong sample of radium is held near the tube.

(*b*) *The Crookes' Dark Space.*—It was early noticed that the length of the Crookes' dark space was of the same order of magnitude as the mean free path of the electrons shooting out from the cathode, and it was often inferred—sometimes stated explicitly—that the dark space represented that part of the trajectory of a cathode ray in which little or no ionisation took place, and that the edge of the negative glow marked the point at which ionisation strongly commenced.

The view here favoured and already explained is that ionisation really occurs all along the path of the cathode stream, but that the negative glow begins at that position where the electric force has fallen to a sufficiently low value to permit of easy recombination. It should be mentioned, however, that the boundary between dark space and negative glow is surprisingly well defined in many cases—notably in oxygen—so sharp as to make it difficult to see how the gradual fall of electric force observed in the dark space can account for it. This is a matter which requires further elucidation.

The length of the dark space measured to the surface of the cathode has been the subject of many experimental investigations, but as the formula expressing it (Aston) is empirical only, and has so far not been interpreted completely, a bare mention of it will suffice :

$$d = \frac{A}{p} + \frac{B}{\sqrt{I}},$$

where d = dark-space length;
p = gas pressure;
I = current per square cm. of cathode (which fills the tube).

A and B are constants for a given gas.

A more fundamental matter perhaps is the cathode fall of potential V (the so-called abnormal fall) which, measured under the same conditions, can be expressed as—

$$V = E + \frac{F\sqrt{I}}{p},$$

where E and F are constants for a given gas.

This fall of potential V represents the greater part of the total potential applied to the tube electrodes, and it is of interest now to examine whether from observations of its value any information can be obtained as to the mechanism of the process (already outlined) resulting in the maintenance of the current.

It will be remembered that there seems little doubt that the electrons (cathode rays) starting from the cathode must owe their origin to the arrival at the cathode of the positive ions.

Now V can be measured with great accuracy under any conditions it is desired to maintain within the tube, and it has been found that if p be increased the above expression holds over a wide range of p ; as p increases, however, the "range" of the cathode rays becomes less and less, the negative glow shrinks in size, as also does the value of d, and the positive column disappears entirely, being represented only by a faint glow on the anode surface. As the pressure is still further increased the current begins to diminish, and at the same time the area of the cathode covered by the glow diminishes also. When this stage is reached the above formula no longer holds, but V is maintained *at a constant value* V_n ($<V$).

V_n is termed the normal cathode fall of potential.

Its value depends not only on the nature of the gas but also on the material of the cathode.

On V_n must depend not only the speed of the electrons from the cathode, but also the energy of the ions producing them. But we find, on looking into the matter closely, that while the energy of the positive ion is sufficient—more than sufficient—to ionise a molecule on the cathode surface, yet, if the fact is taken into consideration that the energy must be given to an electron, the explanation cannot stand, for the ion is many thousand times more massive than an electron, and on this account can only hand over a proportionate fraction of its total energy—this fraction cannot be sufficient.

The most likely hypothesis seems to be that the positive ion on reaching the cathode recombines, radiates, and it is this radiation absorbed in the cathode which causes electron emission. The fact that about 90% of the energy of the ions appears as heat at the cathode is in harmony with this suggestion.

It must not be forgotten, however, that rarely, if ever, is hydrogen absent from a discharge-tube. It is therefore possible that the positive hydrogen ions (protons) may play a unique part in the discharge mechanism. The proton is peculiar as being of exceedingly minute size, and is thus able to give up its energy under particularly favourable conditions. Little is known of this possibility. But it is a noteworthy fact that in a tube where very special precautions have been taken to eliminate hydrogen, water vapour and other hydrogen-containing compounds, a pseudo-high vacuum effect has been observed—a most suggestive experiment.

The actual value of the normal cathode fall, fundamental as it appears to be, has not so far received any reasonable explanations. Efforts, for example, to relate it on the one hand to the ionisation potential of the gas or material of the cathode, or on the other hand to Richardson's thermionic work function have failed. There seems to be some process at work here which so far defies analysis.

(*c*) *The Influence of the Walls of the Tube on the Discharge.*—No account of the vacuum tube, however brief, can afford to neglect the important rôle played by the walls of the tube itself. The tube—usually of glass—is a comparatively good non-conductor, and therefore may become charged with electricity.

In those parts of the discharge where the conductivity is high the effect may be of less importance than in the dark space, for example, where it is low. In this region, owing to the much greater mobility of the electrons, the walls become negatively charged, behaving axially in a manner rather similar to the space charge. More than this, a strong radial electric field is set up which tends to concentrate the cathode rays—and therefore the whole discharge—on the axis of the tube. The effect is naturally more marked at lower pressures when the dark space is well marked.

The effect can be shown in a striking manner by mounting a small plane cathode in the centre of a much wider tube and arranging a closely fitting glass sheath so that it can slide over the cathode, being influenced in some manner from the outside.

If the tube is connected to an influence machine, induction coil, or other apparatus providing a potential which accommodates itself to the resistance of the tube, it will be found that, on sliding the glass sheath over the cathode, the potential rises considerably, and at the same time the originally wide pencil of cathode rays becomes concentrated to a much finer pencil along the tube axis.

The presence of an effect of this sort adds to the difficulty of explaining the otherwise sufficiently complicated discharge.

THE ANODE REGION

It will be noticed from Fig. 1 that there is a rapid increase of electric force near the anode with which is associated a sudden potential change termed the anode fall of potential.

It is doubtless set up by the cloud of electrons (negative space charge) which gathers round the anode.

The value of this anode fall cannot be less than the lowest ionisation potential for the gas in the tube, if we imagine the mechanism at the anode to be the production of positive ions at the surface of the anode by electrons moving up to it. The anode fall cannot be less than this, although it may be greater on this view. In actual fact careful measurements of the smallest possible anode falls do appear to approximate closely to the known ionisation potentials of the gases employed.

The theory of the anode, in general outline, is therefore quite simple. Electrons from the body of the tube are accelerated to the anode under a field which is due partly to the anode itself, and partly to the electron space charge concentrated there. This proximity of electron cloud to the anode produces the anode fall. Its value cannot be less than the lowest ionisation potential involved, but it may assume greater values than this, depending on the extent of the space charge.

The field due to the cathode, or the parts of the discharge associated with it, are assumed to be so far removed, or so completely shielded, from the anode as to produce no effect there.

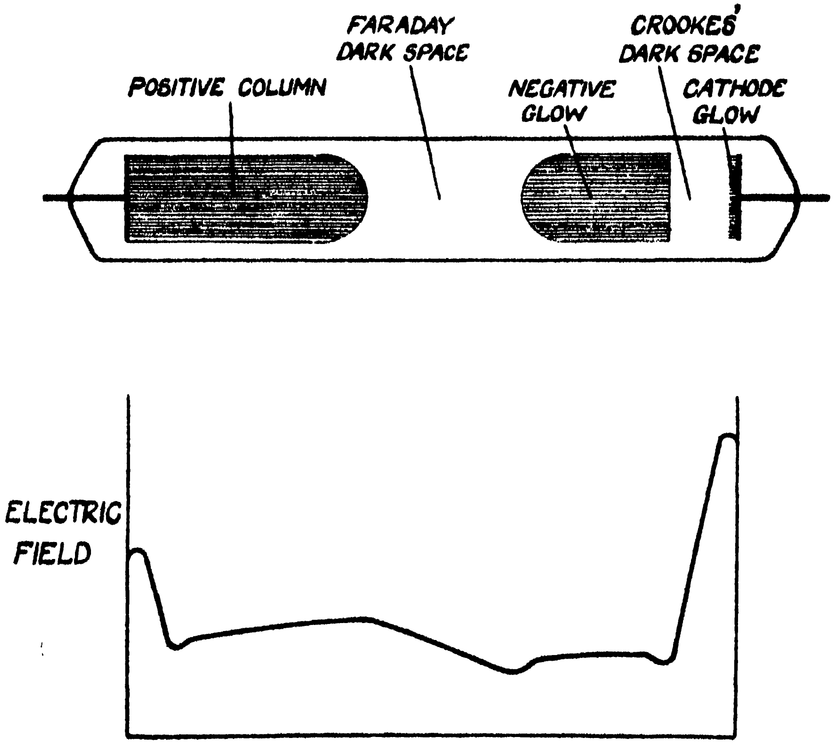

FIG I

The Positive Column

The positive column is separated from the negative glow by the Faraday dark space. Across this region, it is to be supposed, electrons of slow speed move towards the anode, the supply arising from the anode side of the negative glow. A negative space charge is thus set up which raises the value of the electric field more and more as the anode is approached until the electrons move in a field sufficiently high to ionise, the conditions will then be favourable to light emission and the positive column will commence. Generally speaking, in pure gases capable of existing in one form only, the positive column consists of a uniform column of light, in which the electric force is low, extending up to the anode. In the case of long discharge-tubes the main portion of the discharge is composed of this positive column.

An interesting consideration in connection with the uniform positive column is the question of the distribution of positive charge therein. An estimate can be arrived at if certain reasonable assumptions are made. It will be assumed with Holm, for example, that the cathode and surrounding discharge regions have no effect at the points considered, and that, further, the space charge in a plane at right angles to the tube axis is uniformly distributed. This second assumption can only be approximately true, since the positive charge in the column arises, in part at any rate, from the more rapid diffusion of the electrons to the walls setting up a negative surface charge, and this in itself means a radial field. In the case of a tube 1 cm. radius in which a positive column 12 cms. long exists, the curve of Fig. 2 shows the positive charge distribution. The cross-hatched part represents the charge associated with the anode (0·35 unit), while the whole charge in the column amounts to 2 units.

Another point of interest arises here. The positive charge under consideration arises, as has already been remarked, from the diffusion of electrons to the walls of the tube. If λ be the mean free path of the electrons, the effective depth of the layer of gas next the wall from which electrons will diffuse will be comparable with λ. The ratio $\frac{\lambda}{R}$, where R is the radius of the tube, is thus of some importance, since it expresses the fraction of the tube radius from which these electrons may be expected to be recruited. The nearer this ratio approaches unity, the greater will be the potential gradient along the axis of the tube—an important point. This again brings out clearly the importance of the walls in the discharge.

Schottky has recently applied considerations of this kind in an attempt to work out a theory of this part of the discharge. He supposes that, axially, there must be a balance of affairs in which eventually as many electrons diffuse to the walls as positive ions, the final equilibrium condition being determined by their mobilities k_- and k_+ and the potential equivalents of their effective temperatures V_+ and V_-.

He finds that the potential gradient along the tube axis =

$$\frac{2{\cdot}405}{R} \cdot \sqrt{\frac{V_i}{x}\frac{k_+}{k_-}} \cdot (V_+ + V_-),$$

in which x is the distance from the anode of the point considered and V_i is the ionisation potential of the gas.

The formula appears to be in general harmony with the experimental facts for, at any rate, the noble gases.

It remains yet to notice a very usual form of positive column, the striated form.

In this case, the positive column is broken up into bright patches separated by comparatively dark spaces. The effect is particularly marked in impure gases or in those having a complicated molecule, and which, under the action of the discharge, may be expected to break down into other substances.

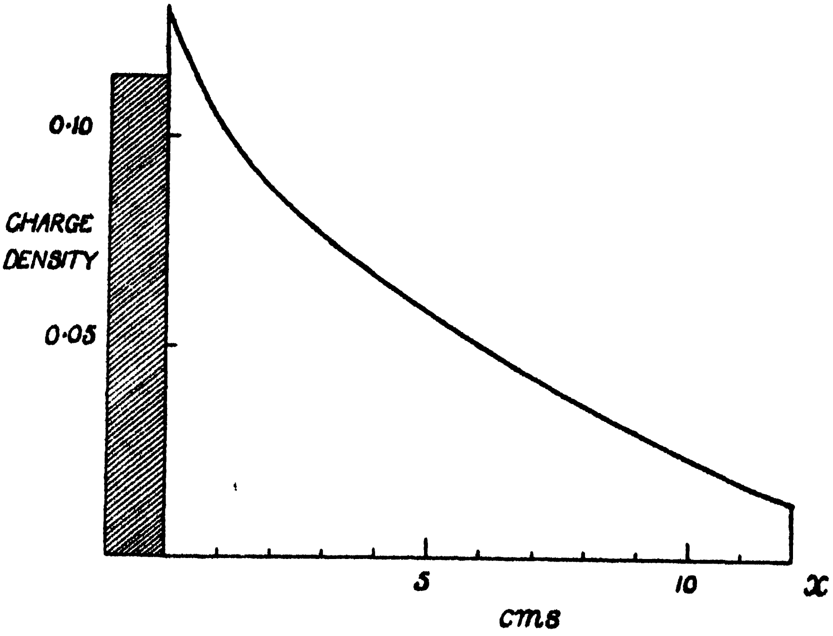

FIG II

It has been supposed that a general explanation of these striated discharges may be based on the supposition that it represents a periodic repetition of the negative glow at the cathode region, or that slow electrons arising in one striation are accelerated along the axis towards the anode until they attain ionising speed, when the next striation is produced.

In hydrogen and nitrogen the distance between successive striæ is given by $C\left(\frac{\lambda}{R}\right)^n$ approximately where C and n depend on the gas. Further, or the bluish striæ in hydrogen, although the potential difference existing between successive striæ may be considerable, the least value compatible with the continuance of the discharge is 11·5 volts—which is very close to the accepted ionisation potential for the hydrogen molecule. In the case of nitrogen, again, the minimum potential difference between striæ is about 9 volts, which suggests once more the ionisation potential of the nitrogen molecule.

This matter of the striations, however, is not so simple as the foregoing would suggest. In hydrogen, for example, the bluish striæ are under some circumstances absent, their place being taken by much broader reddish ones. These do not obey the above-mentioned formula. They sometimes break up into pairs in a most mysterious fashion, and no explanatory mechanism has so far been found to bring their behaviour into some sort of order.

An interesting new effect in connection with the positive column in argon was observed by the writer in 1924.

It was noticed first in a discharge-tube functioning with a hot tungsten cathode, but can be equally well produced with the usual cold cathode.

Within certain limits of gas pressure the continuous positive column observed in a rapidly rotating mirror presents the appearance of Fig. 3*a*, which is a reproduction of an actual photograph. The inclined lines show that the discharge—at any rate so far as luminosity is concerned—takes the form of a series of flashes from the anode to cathode, moving with a speed of between 10^4 and 10^6 cms. per second, and following one another at regular intervals. The heavy horizontal line is a superimposed photograph of the tube in the mirror at rest.

The speed of a flash is often approximately constant along the tube, but nearly always diminishes rapidly in the cathode region, and sometimes shows a progressive diminution of speed during its journey along the tube. (See Fig. 3*b*.)

Sometimes too the photographs show two sets of flashes as in Fig 3*c*. The slower (steeper) flashes are a little more than four times as slow as the quicker (more horizontal) ones.

More often than not after the tube has been running for some time, and the argon has presumably become impure, as the result of liberation of gas from walls and electrodes, the flashes become wavy and of variable speed from point to point in the tube, as in Fig. 3d.[1]

It is tempting to suggest at once that these flashes consist of positive ions moving away from the anode and radiating as they move. This supposition is at once negatived, however,

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[1] There is more than a suggestion in this photograph that this waviness is due to something moving from cathode to anode and disturbing the previously steady state.

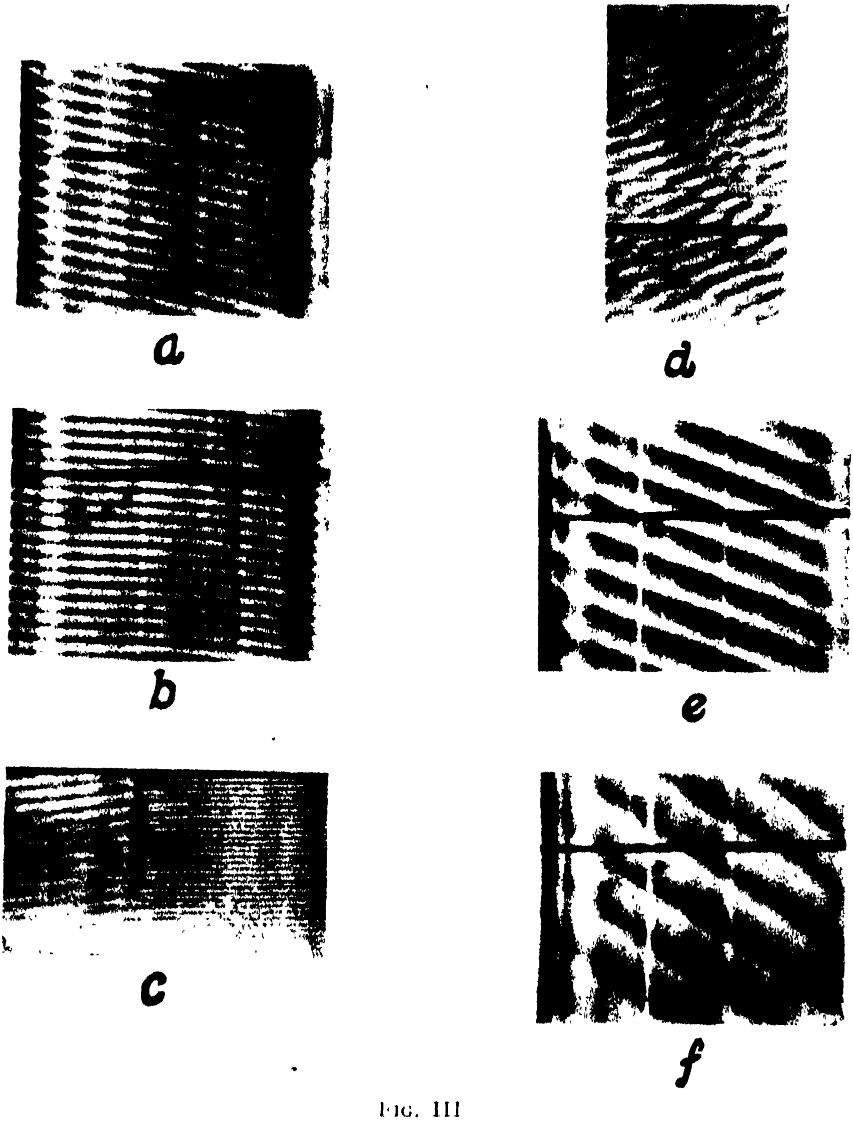

FIG. III

Photographs taken in a rotating mirror of discharge through horizontal vacuum tube containing argon at low pressure with a steady voltage applied to electrodes. Speed of mirror approximately constant in every case; horizontal black line is superposed exposure of glowing tube with mirror at rest.

a, *e*, and *f*, with argon pure but increasing pressure in this order; flashes have about the same speed along the tube, and their separations are roughly equal. In *c* and *d* (viewed here from the other side of the tube, and thus sloping in the other direction) the argon is impure, giving mixed flashes, clearly separated in *c*, but producing unsteadiness in *d*.

by the fact that if the spectrum be examined along the tube and at right angles by a spectroscope of high resolving power no trace of the Döppler effect can be observed, although the observed speed should be enough to produce it measurably.

A way out of the difficulty would be to suppose that the positive ions radiate at a higher frequency than the ordinary luminous light, and that this radiation absorbed by neighbouring neutral atoms at rest produces luminosity in the usual way. This would account for the absence of the Döppler effect, but it is rather difficult to see how on such a view the narrowness of the flashes as seen in the mirror can be accounted for, unless we suppose that the electric field just outside the flash is high enough to prevent recombination. However, on this view many of the observed facts are fairly well co-ordinated :

(1) The supply of ions in a sheet would be kept up in virtue of the external field acting on the electrons in front of it.

(2) The motion of the sheets would depend on the electrostatic repulsion existing between them, each one acting as a " virtual anode."

(3) The occurrence of the two sets of flashes moving with speeds in the ratio 4 : 1 is significant particularly as the spectrum distribution shows strong hydrogen lines near the anode, and their absence or weakness near the cathode. On the present view it would be suggested that the slow flashes are argon ions, while the faster ones are hydrogen ions, the absence of the hydrogen spectrum away from the anode being accounted for on the supposition that all available hydrogen would be used up for ion formation. It is to be remembered too that the effect under discussion only appears when the discharge has been running a short time, long enough for hydrogen to be liberated at the heated cathode region, but not long enough for the amount to be considerable.

The 4 : 1 velocity ratio is roughly what one would expect from the known ionic mobility measurements assuming the same electric field—although an estimate of the field, in these cases sufficiently accurate to provide a critical test, has not so far been possible.

(4) The velocity of the flashes from this standpoint, assuming steady field conditions, should be proportional to $\frac{1}{p}$. This appears to be only very approximately true. The complicating factor comes in that the field under which the flashes must be supposed to move is due to the flashes themselves, and must therefore depend on the current. Oscillograph measurements of this quantity show that only in some cases—and those not differentiated visually—is the current periodic with the flashes :

in many cases it is almost constant, and in others fluctuates only slightly in period with the flashes. It is therefore extremely difficult to associate a definite charge with the flashes so as to arrive at an estimate of the electric force due to them. An attempt has been made, however, and on the assumption that the positive current is carried entirely by the flashes themselves, it comes out that for the electric field due to the flashes on each other to be of the right order of magnitude to produce the observed velocity, they must be unequally spaced, being farther apart nearer the cathode. The differences are quite small, so small in fact as to be only just within the errors of measurement, but with the limited number of observations so far taken this spacing difference does seem to exist.

There is, however, an alternative mechanism which must be mentioned.

It may be that the flashes are produced in some such way as this. Electrons from the body of the tube, attracted to the anode, acquire there ionising speed, and thus produce a kind of double layer of ions and electrons. The ions recombine and emit light, but while doing so act as a virtual anode to attract a fresh supply of electrons. Thus the first double layer is replaced by a second a little farther away from the anode, and the flash appears to move along the tube. It can be shown from this theory that the distance between successive flashes should be nearly independent of the pressure, providing it be assumed that electron atom collisions are elastic, involving no energy losses below the ionising potential. That this is so may be seen by reference to Figs. 3*a*, *e*, and *f*, in which the pressures vary more than 100%, the flash velocities about 300%, while the greatest percentage variation of distance between the flashes is only 5% (*a*, *e*, and *f* are taken in a revolving mirror whose speed is not exactly the same in all three cases).

It is only fair to say that a similar conclusion would be reached on the alternative theory outlined first. In fact, it is very difficult to distinguish between them.

Whatever may ultimately turn out to be the explanation of these most interesting flash experiments, the facts are there, and it may not be out of place in conclusion to point out that these flashes may, in reality, be moving striæ, and that the well-known stationary striæ may be a special case.

PARASITISM IN EVOLUTION

BY SIR ARTHUR E. SHIPLEY, G.B.E., Sc.D., F.R.S.

PARASITES afford remarkably clear instances of evolution. But it is a backward evolution, not a progressive one, that they illustrate so clearly. The Greek word *παράσιτος* is literally " one who eats at the table of another, hence one who lives at another's expense." One who lives at the expense of another tends to undergo all sorts of degeneration. He loses initiative, and exerts himself little, his faculties become dulled, and he is morally lowered. So it is with animal parasites. They may be external or internal, and it is at times rather difficult to distinguish the interrelation of the external parasite with its host from one animal living alongside of another and sharing its food supply (commensalism). External parasites may remain on their host during their whole adult life, or they may remain on their host only during the larval stage, and subsequently develop into free-living adults, or, thirdly, the adult alone may attack its host from time to time, as is the case with the louse, the bed-bug, and the flea.

It is quite possible that the louse is descended from ancestors which never had wings, but this is hardly credible in the case of the bed-bug, which still has what are called wing-scales, or the flea, whose nearest kin are winged ; and yet all three of these ectoparasites are wingless. Evolution has in the case of the flea and the bed-bug deprived these blood-sucking insects of one of the most typical features of an insect's body.

PROTOZOA, OR UNICELLULAR ANIMALS

Amongst the Protozoa, or unicellular animals, mostly microscopic, there are innumerable parasites which attack both plants and animals, and in many cases they do great damage to their hosts. There is a little group of organisms known as PROTEOMYXA, something like amœbæ. Many members of these infest fresh-water algæ, and one species causes great damage to the roots of the Cruciferæ, producing the " fingers and toes " disease in turnips, etc. They are simple organisms, so simple that they manifest very little trace of evolution towards perfect parasites such as the next group shows. These, the group HÆMOFLAGELLATA, are entirely parasitic, and their characteristic home is the blood of a vertebrate. Frequently they cause fatal disease. They have not lost their organs of movement, for they retain one or two whip-like flagella, often strengthened by an undulating membrane. But they show no trace of cell-mouth or of cell-anus, and they are capable of reproducing at an appalling rate. As a rule, they are transmitted from one host to another by sucking insects. The group of Protozoa which perhaps shows the greatest evolution towards the perfect parasite that has and could have no free existence are the SPOROZOA. These include a large number of forms exclusively parasitic, infesting the internal organs and tissues of animals belonging to practically all the classes of the Metazoa, or the multicellular organisms. They exhibit a great diversity of structure and their life-history is very varied. As a typical example we may consider the life-history and structure of a *Gregarina*. *Monocystis magna* inhabits part of the reproductive system of the earth-worm. In its younger stage a minute sickle-shaped cell makes its way towards this part of the body and grows up into an organism well visible to the naked eye, which lies amongst the developing spermatozoa of the worm. The animal has lost all trace of organs of movement. There are no cilia, no flagella, and no pseudopodia, and it is entirely devoid of any cell-mouth or cell-anus. It consists simply of a sac packed with granular protoplasm covered by a thin cuticle. It lives entirely by absorbing through this cuticle the dissolved nutritive fluids of its host. After some time two of these gregarines come in contact and surround themselves with a common cyst-wall. Their nuclei then undergo a process of division. When this is completed each of the mates divides up into a large number of rounded, nucleated naked cells. These unite, two and two, finally forming a lemon-like cyst which contains eight sickle-shaped spores. It is believed that these spores are swallowed by birds, pass out from the bird's body to the earth, where they are again taken up by an earthworm and so what is termed "the vicious circle of parasitism" is maintained. As a rule these parasites are anchored in what may be called the adult state to the cell from which they have grown by a crown of hooks, again evidence of evolution towards complete parasitism. There are many other parasites, such as that causing malaria, which never see the light of day, its whole life being passed in the dark, hot blood of a mammal or in the equally dark muscles and salivary glands of a mosquito.

Thus in the Protozoa we pass from organisms, practically indistinguishable from their free-living relatives, yet living parasitically, to forms which are perfect parasites, forms which conceivably live but in their hosts. They have lost the pigment spot, or eye, they have lost the organs of locomotion, they have lost the power of ingesting solid food, and with that has gone the first dim glimmer of an alimentary tract, the cell-mouth and the cell-anus. In the most perfect protozoan parasites, those just described, we meet with anchor-like hooks or a row of such hooks, in form resembling those of the more complex but equally " perfect parasites," the Tapeworms. They ensure the retention inside the host of the parasite, and are unknown in non-parasitic Protozoa.

ROTIFERS, OR WHEEL-ANIMALCULES

The group of animals known as Rotifers, or Wheel-animalcules are occasionally parasitic. The members of this group are characterised by having a crown of cilia whose rhythmic flickering produces the impression of a revolving wheel. The cilia bring food to the mouth and assist the free-living Rotifers to swim. In the parasitic forms this crown is much reduced, and tends to atrophy. *Albertia* is a worm-like Rotifer which lives inside the body of annelids. The order SEISONACEA, one of the sub-divisions of the Rotifers, are parasitic on the body of *Nebalia*, a small marine crustacean; they frequently have their intestine ending blindly. *Taphrocampa* has its cilia reduced, is without eyes, and is elongated and its body is ringed. Some of the ectoparasites of this group cling to their host by means of the extraordinary teeth which form so prominent a part of the gullet of Rotifers. Although the Rotifers have not evolved very completely towards the perfect parasite the order of their degeneration follows that of other animals: loss of motor organs, reduction of the sense organs, the partial obliteration of the alimentary canal, and the development of organs of attachment.

A few are found living inside *Vaucheria*, a dark green, coarse alga common in fresh water, and another species is not uncommon inside the beautiful revolving *Volvox*. It is rather difficult to draw the line between the animals which are parasitic, for instance, the SEISONACEA on *Nebalia*, and another genus which attaches itself to the surface of sea-slugs and animals which are commensals. But a commensal mode of life is often the beginning of the downward path.

ANNELIDS, OR WORMS

There is a curious group of long, worm-like creatures, mostly marine, though a few are found on land and in fresh water, known as Nemertines. These creatures sometimes reach an enormous length, scores of feet longer than a tennis-court! A few of them are parasitic; the best known of these is *Malacobdella*, which is found living in the gill-chamber of a mollusc. It has developed a large round sucker like a leech. It is perhaps not a true parasite, and may live on the food that is brought by the currents of water to the gills of its host. Others live on Crustacea, but they have at least one characteristic of parasites, an organ of attachment, a sucker, a feature unknown in the free living forms. In these parasitic Nemertines the alimentary canal has no lateral pouches, but as a compensation it is longer than the body, and coiled.

Amongst the true marine worms there is one which lives inside the body of the Gephyrean *Bonellia*, and others live as parasites or perhaps commensals on certain starfish or under the mantle of a *Lepas*, the barnacle. Still other worms spend the early part of their life-history within the body of a group of " jellyfish " known as Ctenophores. A very curious instance of parasitism occurs in the *Bonellia* just mentioned. Here the male has become degenerate and lives inside the reproductive organs of the female. Whereas the female's body may be a couple of inches long, and has a proboscis many inches in length, the male has become a microscopic, ciliated creature which lives in the kidney of the female. But these kidneys act also as oviducts, and there the male is able to fertilise the ova. It has two minute ventral hooks for attachment. The body cavity is solid at both ends, and the alimentary canal is closed at both ends. The nervous system is reduced and there is but one kidney, which acts as a duct for the spermatozoa. Both male and female develop to a certain larval stage without showing any traces of sexual differentiation. But after this stage the development of the male is arrested, and it has evolved this degraded and parasitic habit of life. Evolution, of a retrograde type, has hardly ever produced a more deplorable state of affairs; but until we reach the Vertebrates, and above all the Mammals, the male is almost always the " under-dog."

PLATYHELMINTHES, OR FLAT-WORMS

Let us now consider the example of the flat-worms (PLATYHELMINTHES) with their three main divisions of (i) Turbellarians, (ii) Trematoda, and (iii) Cestoda. The Turbellaria, leaf-like animals, with hardly an exception are free-living and swim about actively in the water, seeking what they may devour. But even amongst this division we occasionally meet with a parasite.

The transition of the Turbellaria into the Trematoda or flukes, or of the Trematoda into the Cestoda or tape-worms, is almost imperceptible. Many years ago I described a parasite from the common sea-urchin which I had certainly taken to be a Trematode. It had the sucker-like mouth of a fluke, and it was only after I had begun to write my Paper that I perceived on the parasite I was dealing with traces of cilia. Other investigators of the same animal had found the cilia in fresh specimens. The presence of the cilia made this animal a Turbellarian ; in their absence it would undoubtedly have been classed with the Trematoda, or flukes. Here we find an example of evolution of what would normally be a free-swimming, active animal into a parasite which so closely resembled members of another parasitic group that it was actually mistaken for them. Turbellaria are carnivorous, living on worms, water-snails, water-beetles, molluscs, and other animals. It is easy to understand how the parasitic habit arose and increased, the free-swimming animal taking refuge in the body of its prey and the organism becoming more fluke-like, the structure changing. As Dohrn showed, " form follows function."

Many Trematoda attach themselves to the outside of higher animals, usually fish. Others attach themselves to the gills or are found in the inside of fishes' mouths. To maintain their position they develop adhesive organs, usually suckers, though sometimes horny hooks are evolved. There are generally in a Trematode two suckers, one surrounding the mouth and one surrounding the opening of the reproductive pore. Gradually they acquire a more pronounced parasitic *facies.* Certain species make their way farther and farther into the alimentary canal of their host and into the glands which open into it, and even into the air-bladder of fishes and into the body-cavity of their host. Although the ectoparasites, or those which live on the outside of fishes, are naturally associated with aquatic life, the more deeply seated flukes are found in all groups of vertebrates, and with some exceptions, such as the liver-fluke of sheep and the *Bilharzia* of man, they do not cause very serious damage. It would be very much against their own interest to kill off their host, in and on which they live. Being, as they are, fixed or sessile—" for their strength," like the people mentioned by the prophet Isaiah, " is to sit still " ; they have lost the organs of movement. Cilia have disappeared in the Trematoda, and so have the muscles which enable free-living Turbellaria to swim so gracefully through the water. Their muscular system is indeed degenerate, for they have no need to go in search of food : the " pleasure of the chase " is denied them. They subsist upon the mucous or other secretions of the alimentary canal of the animals they inhabit, their diet varying with the position they have taken up in the body of their host. Living as they do in the dark and in the higher vertebrates in the warm recesses of their host, surrounded by food, they have lost their sense-organs and their nervous system is at a minimum. They have evolved a condition of things which is very largely centred in the reproductive system, for the chance of their young hitting the right host is very small. Hence it is absolutely necessary for them to possess a highly developed system of reproductive organs, and to lay an enormous number of eggs, which, with few exceptions, must be fertilised. In the parasitic species, as a rule, eggs are produced from which issue larvæ, which do not grow direct into the adult form, but produce by budding other larvæ, so that from one egg we may have hundreds of larvæ formed by budding. But, ultimately, the last form of these larvæ seeks a second host. For instance, the larva of the sheep-fluke takes up its home in a snail that frequents the water-meadows of most temperate countries. When this snail is cropped up by the sheep with the grass, the larva develops in the sheep's alimentary canal into a young fluke that makes its way into the liver. This double host—sheep and snail—increases the odds against any single egg producing a final survivor. For twice in its life-history the Trematode has to hit the right host, and this enormously augments the chances against its attaining maturity. We have thus seen the process of evolution at work producing parasites, undoubtedly a downward step, but still a step in the evolution of effective parasites.

The transition between the flukes and the tapeworms is almost equally gradual. But here we shall find evolution has produced an even greater effect upon the body. Tapeworms are exclusively internal parasites, and with one exception reside in the alimentary canal of the Vertebrata. They may be a few millimetres in length or they run into metres, almost as long as a cricket pitch. This great length is due to the need for producing an incredible number of ova. This is brought about by the body consisting of an enormous number of "segments." There may be many hundreds of these, each packed with eggs, and the hinder one is always dropping off and passing out of the alimentary canal of its host, whilst new ones are always being formed at the other end behind the head. The whole creature behaves as if it were a recurring decimal. Each of these "segments" is almost a single individual, though the nervous system and the excretory system are common to them all. Tapeworms have to anchor themselves to the sides of the wall of the alimentary canal or the peristalsis of the intestinal walls would expel them, and this they do by the suckers they have developed, and by the crown of hooks borne on the head.

On their evolutionary path towards the perfect parasite the tapeworms or Cestoda have attained a stage further than the flukes, inasmuch as that they have completely lost their alimentary canal, of which no trace exists either in the adult or in the larval forms. They live by absorbing through their skin the semi-digested liquid food of their host. Their body has become flattened so that it lies against the internal surface of the intestine of their host like a stamp on an envelope, and it has no projecting processes which might help in dragging it away as the food passes along. The most elementary form of tapeworm belongs to a group known as Cestodariidæ, and here the body might easily be taken for that of a Trematode or fluke, for it is not divided into any segments, and has only one set of reproductive organs. One of this group is the only Cestode found outside a vertebrate, and it occurs in a minute fresh-water worm. Allied forms occur in the sturgeon and in other fish.

Another sign of degenerative evolution is the fact that, as a rule, the eggs do not pass out of the segment discharged from its host on to the earth by any definite channels, but as the segment wriggles about on the earth it gradually undergoes a dissolution and the eggs are left behind on the grass or earth. In this way the eggs of a common human tapeworm are dispersed, and if a pig be rootling about in the earth some of the ova will pass into its alimentary canal, the eggs will hatch out and bore their way into the muscles of the pig, and the meat of this particular pig is known as " measly." Should measly pork be eaten insufficiently cooked, as is often the case in Central Europe, the larval tapeworm will grow into the adult in the intestine of man.

Two other groups of organisms which have evolved a profoundly parasitic habit and structure are some minute creatures possibly allied to the flukes. Here, again, there is no alimentary canal and no trace of it. These organisms are grouped together under the uncomfortable names of DICYEMIDÆ and ORTHONECTIDÆ, and they live parasitically inside free-swimming Turbellaria or in the kidneys of cuttlefish or the brood pouches of brittle-stars. In the first group these microscopic animals have a single layer of ciliated cells surrounded by a central mass of homogeneous cells, some of which form eggs or ova. In the second group there is a central mass of protoplasm not divided into cells, with nuclei scattered through it. In this mass both eggs and spermatozoa are ultimately formed, but in different individuals. The whole animal consists of so small a number of cells that they can be counted. It may be mentioned that the laying of the eggs is accompanied by the dissolution of the mother's body, a not uncommon price paid by maternal parasites.

NEMATODA, OR ROUND-WORMS

Another large group of animals which show a progressively degenerate development are the Nemathelminthes. They usually have separate sexes. There are three main groups. The Nematoda, or thread-worms, is much the largest of the three, and its members exhibit a great variety of life-histories. For instance, there are forms which live in both a larval and an adult condition in water or in the earth or in decaying organic matter. A second group of examples are the round-worms, which cause so much damage to wheat and to tomatoes and other plants. Their larvæ live in the earth, and their sexual forms in plants. The reverse happens in still another group, where the larvæ live in animals, and after their death and decay they are set free and develop into sexual adults in the earth. Or both larval and adult male and female may pass their life within one animal. There are still other varieties of modes of life which space does not permit our mentioning. All these parasitic round-worms are devoid of certain organs usually associated with a free life. They have no organs of locomotion or of sense, except certain tactile papillæ, and the nervous system is very simple ; but there is a tremendous increase in the powers of reproduction. A great number of eggs are laid ; the parasite may at some time of its life reproduce parthenogenetically, but asexual budding and fission are unknown in this group. It has been calculated that a single Nematode may produce over 60,000,000 eggs. This enormous reproductive power is necessary if the offspring are to find the right host. Nematodes show perhaps less trace of parasitism than the other two groups of Nemathelminthes. But the elongated, thread-like body and the structure of the cuticle enable them to wriggle about freely in the soft tissue of the host and to attain that part where they wish to live. They have, further, a great power of resisting desiccation. They may be dried up for months, and even years, and resume their activity on being moistened. Their great success as parasites is further shown by the very great variety of their life-history and by the great number of species.

One of the most highly evolved parasites amongst the Nematodes—that is to say, the species which has lost most of its normal features, and has become but a sac of ova or spermatozoa—is *Atractonema*, which lives in the body-cavity of a

Cecidomyid fly. At the time of sexual maturity the uterus and vagina undergo a prolapsus and are pushed out from the hinder end of the body. This swelling increases until it first equals the rest of the body of the Nematode in size. This condition of things is carried still further in a species known as *Sphærularia*, which lives in the body of the bumble-bees.[1] Here the prolapsed and evaginated sac grows with great rapidity and in a few weeks it has increased in length from 0·25 mm. to 15 mm. and its volume has increased 60,000-fold. Curiously enough, according to one observer, this great increase in growth is due to the swelling of the individual cells and not to their multiplication. The female which has produced this abnormal growth gets relatively smaller and smaller until it looks like a tiny hair attached to a skein of wool. It finally drops off. The sexual larva arising from the eggs in this sac leaves the body of the bee by means of the alimentary canal and lives in the damp earth and moss without taking any nourishment until the time comes when it becomes sexually mature. The fertilised female makes her way into a bumble-bees' nest in the autumn, and this accounts for the fact that it is the queen bumble-bee only that is infected, for the workers and males are now moribund or dead. Like other parasites its presence affects the fertility of the host, and no infected queen-bee ever gives rise to a new nest. The common genus *Heterodera*, which gives rise to galls on beetroots, is another example of the female becoming simply a rounded mass of eggs; these give rise to larvæ which ultimately escape from the uterus and very justly cause the death of the mother.

The second group, the Nematomorpha, are sometimes known as Hair-worms. They may be seen swimming about in fresh water, having emerged from the body of insects in which the larval stages have been parasitic. Both in this group and in the Nematoda the alimentary canal is formed of a single layer of cells and it is very rare to find any food in its cavity. In one member of the Nematomorpha the mouth is minute and opens into a fine tube which pierces through the substance of a single cell; but the lumen, before it reaches the tail end, dwindles away entirely, and there is no trace of an opening at the hinder end. Obviously it is developing along the lines of disappearing altogether.

The third group of Nemathelminthes is the Acanthocephala, which occur in the alimentary canal of vertebrates, mostly those of aquatic habit. On the fore part of the body there are several rows of bent-back hooks which firmly fasten the parasite to the tissues of the intestine of the host. The outer skin has suffered a degeneration and consists of a mass of protoplasm with no cell limits; in this mass occur a number of amœboid nuclei, which creep about. With the exception of a few sensory papillæ, all sense organs have disappeared. All traces of alimentary canal have absolutely gone, and like the tapeworms these creatures live entirely by absorbing through the skin the nutritive and partially digested food of their host.

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[1] They are living now, or were living a few years ago, in the bodies of the bumble-bees, who build their hives in the grassy mound which supports Milton's Mulberry Tree in the garden of Christ's College.

The remarkable fact that cilia are not found in the Nematoda and in the Nematomorpha may be associated with their parasitic habits. But cilia are also absent in the great group of Arthropods (Insects, Spiders, Crustacea, etc.), which have some parasitic forms, but not many in comparison with their enormous number of species.

CRUSTACEA, OR CRABS, SHRIMPS, ETC.

The highly developed group of Crustacea affords many striking instances of degenerative evolution due to a parasitic habit of life. The evolution is gradual, and in its earlier stages affects only certain organs of the body; but as the parasitic habit becomes more and more embedded in the host, evolution leads it into a state where it is little more than a shapeless sac of ova or spermatozoa, without the faintest resemblance to an ordinary typical crustacean, such as a cray-fish, or a shrimp. There are three main groups in which this evolution towards the perfect parasite are apparent. The first group is known as the Isopoda, and normal members of this group have a typical segmented body with normal legs and an abdomen or hinder part. In the free-living Isopoda such as the woodlouse—one of the very few Crustacea which lives on land—the sexes are separate and resemble each other, as they are and do in a lobster; but when the creatures become parasitic and hence stationary they develop either a marked difference in the two sexes or they become hermaphrodite. Certain Isopods which are parasitic in the mouth and on the gills of fish are male when young, but turn into females at a later period. In practically all cases the parasites are derived from active swimming larvæ with fully developed crustacean characters, sensory antennæ, swimming legs, and so on. If we take the case of *Bopyrus*, which is frequently found forming a gall-like swelling on one side of the thorax of a prawn, the actively swimming larvæ pushes its way in amongst the gills of its host. The female larva then becomes asymmetrical. The limbs dwindle on one side, often disappearing altogether, and a large brood-pouch is formed. The males, on the other hand, become dwarfs. Still more remarkable parasites are included in the family known as CRYPTONISCIDÆ. These are actually parasitic on the Rhizocephala, which in their turn are parasitic on crabs; and here, with great self-restraint, I refrain from quoting Dean Swift. The CRYPTONISCIDÆ are also hermaphrodite, being first male and then female. They have fully developed eyes and limbs, and attach themselves to their host by means of thoracic claws. Ultimately inside them a small, grub-like creature appears, provided with but one pair of short stout limbs. The mouth has become tubular and piercing, and through it the parasite sucks up nutriment which the Rhizocephalan has, in its turn, derived from the body of the crab. The intestine ends blindly. The eyes disappear, and the heart may also vanish. The eggs develop inside the body of the mother and escape by the bursting of its body-wall. A still further complication occurs since a second form of male individual is sometimes found attached to the female. This is regarded as a male larva which, for some reason or other, has been cut short in its metamorphosis.

A second great group of Crustacea in which evolution towards complete parasitism is very common is the Copepoda. There is one form known as *Argulus*, the so-called " fish-louse," which attaches itself to the scales of fishes, though from time to time it leaves its host and swims actively about. It presents the following parasitic modifications. The anterior antenna forms a hook for clinging to its host, the mouth is formed of a large tube with a piercing style, and the second maxillæ have been modified into large sucking discs which help the creature to adhere to its host. The males are smaller than the females, but more active, and the eggs are not borne by the female in two egg-sacs like those elsewhere found in other Copepods, but are deposited singly on surrounding objects. A curious feature in the family MONSTRILLIDÆ is that they are parasitic in their larval stage, but become active and free-swimming in the adult stage, although even then there are no mouth-parts. The mouth is minute, leading to a small stomach which ends blindly. The only appendages on the head are the first antennæ, but there are well-developed copepod legs on the thorax which enable the animal to swim actively. The egg gives rise to the typical crustacean larva known as the Nauplius, which bores its way into a certain marine worm and comes to anchor in the blood-vessels of its host. It then loses all trace of crustacean habit. The eyes disappear and the body is reduced to a minute sac consisting of more or less undifferentiated cells. It then begins to grow, and, first of all, produces the second antennæ, which act as nutritive organs conveying the nutriment from the blood of the host to the body of the parasite. Later, another pair of appendages, the mandibles, may be differentiated and grow into long, root-like processes which also absorb food. Then it leaves its host's body by rupturing the body wall and leaving behind it the modified mandibles and second antenna. Another parasitic family is the DICHELESTIIDÆ. Here the male and females are both parasitic on sponges, ascidians, and echinoderms. The segmentation disappears, the thoracic limbs become formless, fleshy lobes. The mouth becomes a siphon with piercing stylets which represent the mandibles. These creatures live for the most part on the gills of various fish. Other parasites found in the same position belong to the family ERGASILIDÆ. Here the second antennæ become claw-like, but there is no siphon, and the body loses much of its segmentation. Perhaps the CHONDRACANTHIDÆ present the most extreme forms of parasitism. These, again, live in the gills and in the mouths of certain fish, such as the gurnet and plaice, skate and sole, and many others. The female loses almost all trace of crustacean origin. Its body is produced into lobe-like, sometimes forked, projections. As is the case in the Cirripedes the males are pigmies and may swim about independently. The female does not evolve its peculiar degenerate form till after it has been fertilized, when it increases in size and becomes little more than a lobed sac of ova. The lobes to some extent represent the appendages. In the CALIGIDÆ, which are ectoparasites in the gill-chambers of fishes, the males are smaller than the females and were for a time regarded as of a different species. The LERNÆIDÆ have lost even the faint traces of segmentation shown by the CHONDRACANTHIDÆ. The females, when adult, have processes which break up into terminal branches and they burrow deep into the skin of their host, being found in the body cavity or even in the blood-vessels. The female body becomes a shapeless mass, but it still retains that constant character of the Copepods, the two egg-sacs. In the LERNÆOPODIDÆ, common enough on perch or trout, the two maxillipeds of the females have fused their tips, forming a horny pad which is embedded in the host.

But enough has been said to show that in the Copepoda there is a marked evolution from an active, free-swimming organism with all the characteristics of the crustacean larva to a degraded sac of ova "without form and void," but for a central mass of ova.

A third group of Crustacea which shows a marked evolution towards a parasitic mode of life and its corresponding alterations in the normal structure of the animals is the order Cirripedia, or barnacles. This is the only group amongst the Crustacea that has uniformly become sessile—that is to say, the adults have lost their powers of movement and have become fixed, either by a broad base or by a stalk. Sessile animals usually show certain modifications which are well marked amongst the barnacles—to use the common name of this group. The larval Cirripede is a typical nauplius with three pairs of appendages, a median eye, and an alimentary canal. The nauplii of this group are characterised by a long process projecting from the body, conspicuous amongst which are the so-called frontal horns. This larva changes, as so many nauplii do, into a secondary larval form known as the cypris stage, from its resemblance to that genus amongst the Ostracods ; and it is in this stage that the animal fixes itself. The nauplius swims freely near the surface of the sea for some days and thus serves to spread the species. The cypris stage is also motile, and it swims about by means of six pairs of bifurcated thoracic legs until it finds a favourable position on which to fix itself. In the case of *Lepas*, the stalked barnacle, this is generally found on the submerged parts of a ship or of floating logs. The bifurcated swimming legs are then cast off and are replaced by six pairs of " biramous cirri." The cypris fixes itself by means of the first antennæ, at the base of which there is a large cement gland secreting a sticky substance. Two lateral folds grow out which ensheath the body, leaving a slit along one side, and in these folds various calcareous plates are formed. The folds can be bent apart and the biramous cirri protruded. It is by their movement that food is brought towards the mouth. In fact, as Huxley said, the animal is standing on its head and kicking its food into its mouth by its legs. In all cases the abdomen is very reduced. Corresponding with the fixed habit of life there is evolution towards the simplification of structure. The animal that is inactive does not need sense organs, and, as a rule, the eye of the nauplius tends to disappear in the adult barnacle and quite disappears in most cases. Sense organs are at a discount, the chief ones left being the sensory hairs on the biramous cirri. In the stalked species no gills are developed, and in all forms the heart has disappeared and the circulatory system is poorly developed. On the other hand, reproductive organs are conspicuous and like many other sessile animals the barnacles are hermaphrodite. As a last resort they can fertilise their own ova with their own spermatozoa.

But parasitism has produced even greater changes in certain genera. One widely distributed and large genus, *Scalpellum*, lives at great depths in the ocean fixed on to corals, empty shells, rocks, or colonies of Polyzoa or hydroids. This has developed three kinds of modes of reproduction: (1) The hermaphrodite: individuals self-fertilize each other. (2) In the great majority of species, including *Scalpellum vulgare*, the individuals are hermaphrodite; but there are present inside the valves in a little pocket a varying number of minute males, almost microscopic. These minute males have developed such a degree of parasitism that the most highly developed—or, rather, the most highly degenerate—forms are little more than bags of spermatozoa. But there are different stages, and in another species the males retain to varying degrees the ordinary organs of the adult, but always in a greater or less degree of degeneration. (3) In a few species of *Scalpellum* the individuals are diœcious, *i.e.* the females bear on their bodies dwarfed males. In another genus known as *Ibla* there are even smaller dwarfed males which retain their second antennæ partly embedded in the body of the female. These have retained two pairs of their thoracic cirri, and eyes are still recognisable. Here the development towards parasitism is not so great as was the case in the *Scalpellum*. Then, again, in another species of *Ibla* we find hermaphrodites which still harbour within their mantle complementary males. Members of the order Acrothoracica burrow into the shells of molluscs or into coral rock. Here, again, the sexes are separate, the female having a number of teeth by means of which she bores her burrow, and she is attached to the sides of the cavity by means of a horny disc, and it is upon this disc that the dwarf complementary male, which has lost all its organs but its reproductive system, is fixed.

But the most remarkable case of hermaphroditism in barnacles occurs in a group known as Rhizocephala. It is less than 100 years ago that the crustacean nature of barnacles was demonstrated. Before 1830 these animals were grouped amongst the Mollusca; and it has taken all this time to work out what little we know about this order. The Rhizocephala are parasitic on other Crustacea, some infesting hermit crabs, others shrimps; and for the most part they are solitary. They begin life as an ordinary nauplius form with its frontal horns. This is followed by the typical cypris larva, and it is this stage which turns into the very remarkable creatures which live half embedded in the tissues of their host. In the case of *Sacculina* the nauplius has no alimentary canal, and neither has its cypris form. This latter, after living a free existence, seeks out a crab, and by means of hooks on its antennæ attaches itself to a hair on any part of the crab's body. The antennæ then pierce the soft area which surrounds the base of such a hair, and from its body exudes a small mass of similar cells which, passing down the antennæ, enters the body of the crab. Here it reaches the blood-stream and is carried along till it arrives at the intestine of its host in the neighbourhood of the thorax. It attaches itself to the intestine, and proceeds to throw out roots spreading like the roots of a tree. These roots penetrate or permeate all through the body of the crab, embracing all organs which are not absolutely vital, and through them nutriment is absorbed. After a time a "central tumour," as it is called, grows out from the roots towards the lower part of the intestines, and in this tumour the future organs of the adult become established. A mantle cavity is excavated, and whilst the "sacculina interna," or the roots, retains its position, branching all over the body of the crab, the central tumour protrudes to the exterior at the point where the thorax and abdomen join. It presently causes deterioration in the epithelium, or skin of the crab, so that when next the crab moults a small hole is left in its integument. Through this the so-called "sacculina externa" projects. Having once established itself, by some action, probably chemical, the moulting of the crab is brought to an end. Otherwise, at the next moulting the "sacculina externa" would be torn from the "sacculina interna." This amazing metamorphosis is difficult to explain. How the animal finds its way to a hair of the crab, how the undifferentiated mass of cells reaches the exact spot it wishes to attain before the branching begins, and how the "sacculina externa" comes to the right position for extrusion, are matters of speculation more than of knowledge.

Rhizocephala are, with one exception, all hermaphrodites, and they reproduce by a continual cycle of self-fertilisation. One of the most remarkable features about these parasites is that they have a great influence on the sexual activities of their host. The generative glands of the crab become reduced or modified, and the secondary sexual characters are changed; 70 per cent. of male crabs infected with *Sacculina* take on the external characters of the female. The abdomen becomes broad and egg-bearing appendages become developed. On the other hand, the chelæ are markedly reduced. Yet the female crabs which are infected by the parasite show little change, and beyond the degeneration of the ovigerous appendages they do not develop any male characteristics. If the *Sacculina* be removed from the crab there is a great tendency for the latter to return to its normal condition. But the males, instead of developing only a testis, develop an hermaphrodite gland which produces both ova and spermatozoa. But in the case of a female crab male cells are not developed when the parasite is removed.

INSECTA, OR INSECTS

The highest class of animals which has developed in a backward way into parasites is the Insecta, and parasitism is met with in many of its orders. As a rule the female lays the eggs in the body of the host, and from this the larval grub will emerge, but in the case of vertebrate hosts the eggs are often fastened to the hairs or feathers. In many cases parasitism in an insect is associated with the entire absence or feeble development of the respiratory system, and in that case the parasites derive their oxygen from the blood of the animal in which they are living; but in some cases, as in the roundworm, the tapeworm, or the larva of the bot-fly, which lives in the oxygen-free contents of the alimentary canal of man, horses, or cattle, etc., the necessary energy is produced by the breaking down of glycogen obtained from the host.

We have already alluded to the semi-parasitism of the flea and the louse. In the latter insect, as also in bird-lice, which live on the cuticle or feathers of birds, the eyes are greatly reduced and in some are even absent. In the case of the Coleoptera, or beetles, a hypermetamorphosis may occur—which long word indicates that the larva passes through two or more different larval stages—generally associated with a change in the surroundings. This is the case in parasitic beetles of the family STAPHYLINIDÆ—devil's coach-horses—and in many other insects. The last-named family includes more than 13,000 species, usually small and inconspicuous. The larvæ are usually somewhat like the well-known silver fish and in one genus, *Aleochara*, the newly hatched larva gnaws its way into the pupa of certain Diptera, or true flies. It then undergoes a metamorphosis and changes into a cylindrical grub which is less active than its forerunner, and shows many obvious traces of degeneration. Many of the family RHIPIPHORIDÆ have larvæ which are parasitic upon other insects. *Metoecus* is common in wasps' nests. Its newly hatched larva, which is black in colour, emerges from the eggs which have been laid on old wood and may be conveyed to the wasps' nest by the active wasp imago. It burrows its way into the body of the wasp larva and gradually devours the whole soft tissues of its host. It then penetrates into the "cell" in which its victim lives, and as many as twenty or more may be taken from a single nest. Other species of the same family attack other wasps. *Symbius* is an endoparasite of the so-called "black beetles," though they are neither black nor are they beetles. The female retains her larval shape, and is without wings. It passes its whole life in the body of its host.

There is a somewhat isolated group of insects known as the Strepsitera, which are parasitic in the bodies of bees and wasps and bugs. These extraordinary insects are by some authorities classed with the Coleoptera. Their life-history is as follows. The egg, whilst still within the body of the mother, which, it must be remembered, is a parasite shut up inside the body of some hymenopterous or hemipterous host, gives rise to a small, active, six-legged larva, known as a "triungulin," so-called from the three processes at the end of each tarsus.

A single mother may give rise to many hundreds of these microscopic, active larvæ, which find their way on to the outside of the body of the host. Sooner or later they reach the larvæ of the host, and, boring their way through the skin, enter these larvæ and commence to feed on their fat body. When the host's larva pupates, the larval parasite pushes one end of its body through the soft membrane uniting two of the abdominal segments. When the host emerges as a perfect insect the parasite, if a male, leaves the body of its host through the integumental membrane and flies away in search of a mate; on the other hand, the female parasite remains in the host's body with the head and thorax projecting between two of the abdominal segments. She is wingless and legless, being little more than a bag of eggs giving rise to active larvæ which escape into the brood-pouch, a space between the ventral surface of the body and the persistent larval cuticle, eventually gaining the exterior of their host via a brood-canal. The male seems to live but a very short time—in the case of *Xenos* about twenty minutes—whilst the male *Stylops* lives a day or two, the whole time being spent in a feverish and frenzied search for mates. As a rule but one *Stylops*, or at most two or three, live in one host; but they are extraordinarily prolific. Ten specimens of *Xenos* have, however, been found in the body of one wasp, *Polistes*. Some observers maintain that parthenogenesis is met with in this Order, but the matter requires further investigation. The larvæ probably leave their host when the latter is on flowers or in the nest. The bodies appear to be nourished by the nutritious juices of the host, filtering through the very delicate skin of the parasite. Both male and female bees, etc., may be attacked; but the female seems to be the most frequent victim, and the presence of the parasite apparently affects the secondary sexual organs, very much as is the case with the parasitic crustacea. In fact, the females have the pollen-collecting apparatus diminished and their hind-legs resemble those of the males. The colour usually changes to that of the male, and the sting is curtailed. The reproductive apparatus of the male is reduced.

Many genera of Hymenoptera—bees and wasps—are parasitic, and are then frequently capable of both sexual and parthenogenetic reproduction, the latter method generally giving rise to males. At least half the family known as the Cynipidæ—gall-flies—are parasites, and the whole of the Ichneumonidae and the Proctotrypidæ and almost all the Chalcididæ. Associated with this habit of life is the phenomenon Polyembryony, which means that the embryos divide by repeated budding until from one egg one may get as many as a hundred or more embryos just as was the case in the flukes of Trematoda. Each of these young embryos may develop into a larval parasite, pupate, and develop into males or females. This accounts for the fact that in some cases more than 3,000 parasites have been seen to issue from the larva of a single moth.

The Cynipidæ lay their eggs in plants, and their presence induces the formation of galls such as the well-known oak-apple. They are generally provided with a long ovipositor which pierces the tissue of the plant, and some species will lay their eggs in the galls whose existence is induced by other species. Other members of the family lay their eggs in a great variety of insects, chiefly on plant-lice or in the larvæ of flies. Many of the Cynipidæ are parthenogenetic, and in some species no males have ever been seen. The larvæ are maggot-like, and have lost all their legs. The Proctotrypidæ again pass the earlier stages of their life inside the body of other insects. They are minute, and lay their eggs occasionally in spiders. Some are aquatic, and infest the larvæ of dragon-flies. Polyembryony exists also in this family and aids in the increase in the number of specimens. The larva is very reduced, and in the species known as *Platygaster* has become rather like the typical nauplius larva of the Crustacea. This larval form changes into an almost unsegmented oviform larva devoid of all appendages, and this again changes into a grub-like larva. All these stages live in a minute fly known as *Cecidomyia*. The group contains some of the smallest of insects. Then there is the family Chalcididæ, which are often brilliantly coloured. Many of these also live in plant-galls, feeding on the larva of the gall-makers. Others attack caterpillars, and others again only pupæ. The female of *Leucospis* attacks Mason Bees, piercing through the hard cell of that creature. Only one parasite can live in the bee larva, although by a mistaken waste of material often more than one egg is deposited. The larval form is a slightly segmented grub, rather arched, and it moves about by means of bristles. It seems to suck the juices out of its host, for whilst the *Leucospis* larva grows the bee larva shrinks and shrivels but does not die for three or four months. After this the larva will remain for nearly a year in the bee's cement cell. All these insect larvæ have evolved traces of the complete parasite—that is to say, they lose their locomotor and sensory organs and have devised several methods for increasing their reproductive activity.

ACARINA—MITES AND TICKS

Most ticks are ectoparasites for a large part of their life, piercing with their sucking proboscis the skin of various vertebrates whose blood they suck. Like other blood-sucking animals, they frequently distribute disease.

Many mites are parasitic or semi-parasitic. The harvest-mite is a little creature of a brilliant scarlet colour, the cardinal of the mite world, with a beautiful satiny sheen decorated here and there with black spots. The adults feed upon insects and other mites. It gives rise to a great number of eggs. An enormous number of six-legged larvæ emerge from these and swarm all over the grass ready to attack any warm-blooded animal. They pierce the skin by means of a proboscis and their presence produces acute irritation. They can be dislodged by applying a drop of petrol or benzine, both very inflammable. If they are pulled off the proboscis remains behind and may set up further trouble. Others which live amongst cereals are very apt to attack labourers who are dealing with grain. There is, further, a considerable series of mites which, as adults, burrow in the skin. One known as *Demodex* inserts its whole body in the sebaceous glands of mankind and other mammals. It has become very elongated, and the hinder part of its body is ringed. Unlike other mites, it is five or six times as long as it is broad. It is very small, and its legs are reduced to short stumps. It appears on the skin as a kind of black spot which may occasionally be observed on people's noses or in the passages leading into the ear. Then we have the itch-mite, *Sarcoptes*, which gives rise to a definite disease. These creatures pierce a tunnel in the skin and the fertilised female resides at the deepest end of the burrow, along which the eggs gradually get pushed towards the outer opening. The most advanced in their development are thus those nearest the external orifice. As the burrow is narrower than the length of the mother's body she cannot turn round and escape, but she does not seem to mind that ; still, as a matter of fact, she is simply digging her own grave, as she can never escape. They are said to live for two or three months and to lay two eggs a day, and the eggs are very big. There are also a large number of endoparasitic mites. You can find mites living in the body-cavity and air-sacs of birds. Others with a long name, *Nephrophages*, inhabit the kidneys of man, or at any rate, of a Japanese man. One of the most curious parasites is a bird's feather mite, which lives in the hollow quill; and another causes much damage amongst chickens by producing a leg scab which is a great worry to poultry keepers. Many others attack plants.

Both ticks and mites which live parasitically are modified by the acquisition of organs of attachment; their legs often end in suckers and their proboscis is armed with curved teeth. Still, on the whole, they do not show any very striking divergences from ticks and mites which live freely, and, after all, most members of this class pass part of their life in the open.

Mollusca, or Mussels, Snails, etc.

Amongst the Mollusca there are far more parasites than one would expect to find in so highly organised a group. It is difficult to draw a line between the true parasite which nourishes itself by eating or absorbing the tissues or fluids of its host and the commensal, which simply lives on its host and shares its food supply, but does not devour any portion of its body. Many boring molluscs make channels in sponges and corals, frequently adopting the colour of their putative host. One does not know whether they eat their softer parts or whether they share the food supply which is drawn to the sponge or coral. Others are parasitic on Echinoderms, piercing the tissues by means of a long proboscis and sucking up the digested and elaborated juices of their host. These occur not only amongst the sea-lilies but amongst the star-fish, whose comparatively soft skin renders them a convenient prey for the parasitic molluscs. As a rule, the proboscis of the mollusc is long and often furnished with a sucking pharynx which pumps the food into the parasite. Other forms penetrate into the body. Several species are found on the brittle-stars, and sea-urchins also harbour others. Perhaps the sea-cucumbers are the greatest sufferers, a number of very curious forms making their home within the bodies of these Holothurians. Some have evolved such a long way towards the completely parasitic habit and structure that it is difficult to assign them their right position in the molluscan scheme of classification. One form, *Entoconcha*, is fixed by its mouth end to the blood-vessels of certain species of *Synapta*. Another similar genus has its head attached to the muscles of another sea-cucumber. There is a small bivalve which is common enough between the tide-marks of Zanzibar. In its gullet is found a small mussel, *Entovalva*. This animal is very large for its shell, which seems almost rudimentary. In the alimentary canal of the same animal lives a small univalve not moving about, but fixed to a portion of the stomach-wall by a long proboscis which pierces into the body cavity of the Holothurian. The proboscis is nearly three times as long as the body of the parasite and beset with sharp hooks which retain it in its position. Other degenerate molluscs have been found under the scales of a species of "sea-mouse," one of the marine worms. The common shore-crab, *Carcinus*, harbours a mollusc, but whether it lives on the tissues of its host does not seem quite clear. Molluscs frequently inhabit members of their own class, but in many cases this seems to be more for protective purposes than for actual nourishment. Ascidians also are attacked, certain molluscs laying their eggs on one of these degenerate animals, and others occur embedded in the test of a species of Ascidia and other allied species. Parasitic molluscs undergo the usual evolution that parasites pass through. They lose their colour and are often transparent, or are of a somewhat milky-white appearance. Absence of light may account for this. The two species which have been mentioned as living in the muscles and blood-vessels of *Synapta* have lost all traces of respiratory and circulatory organs and their nervous system is unknown. A suctorial apparatus reinforced by the presence of hooks helps to maintain the parasite in the position within the host it is infesting. Losing any need to move about, in many cases the "foot" has disappeared, whilst the proboscis may become enormously elongated, and eyes are generally wanting, but not always. The radula, or tongue, as it is called in molluscs, may entirely disappear or become markedly modified. All these parasitic molluscs can be derived from free-living and normal species, but evolution has produced in them marked modifications which tend to an increased adaptation to a lazy life.

Fresh-water mussels have a very peculiar life-history, for their larva becomes for a time parasitic in fishes. The eggs are laid in the spring or summer, and make their way into the spaces in the outer gills of their mother. Here they undergo the first stage of their development, which takes two months. They now develop into a larval form known as a Glochidium, and are ejected in a stream of mucus with the water which has been used for breathing. They are especially apt to be ejected when fish come into the neighbourhood of the mother. Each glochidium possesses a bivalve shell with a very strong piercing hook on the edge of each valve. There is a transverse muscle which brings the shells together, and a long filament or "byssus" which seems extremely sensitive to the presence of fish. For the most part they lie at the bottom of the water in the mud. But should a fish come in contact with them they become violently excited and make every effort to lodge themselves on its fins or gills. Should they succeed they gradually become embedded in its tissues, and remain there from two to five weeks, after which they make their way to the outer waters and grow up into young fresh-water mussels. Of course, a very high percentage of them never reach their host and perish miserably in the mud. How they detect the presence of the fish, whether by smell or by contact, does not seem quite clear; but the tail of a recently killed stickleback put into a watch-glass containing glochidia throws them all into a wild agitation which lasts for some seconds, and then they appear exhausted and lie placidly with widely gaping shells. Fish show a marked dislike for these little larvæ, and, if they venture to eat them, invariably spit them out with emphasis.

VERTEBRATA

Amongst the Chordata (Vertebrata) there are very few parasites, and they are confined to the fishes. There is a family of bony fishes known as FIERASFERIDÆ which have elongated, attenuated bodies with a tail without the caudal fin. There is only one genus of this, with about ten species, and its larval form, which was at one time mistaken for a distinct species, is known as *Encheliophis*, and it is without pectoral fins. The adult Fierasferit spends the greater part of its life inside the Holothurians, or sea-cucumbers. It retains an embryonic condition of its kidneys. This fish lives in the alimentary canal, or the respiratory tubes of sea-cucumbers, or in the alimentary canal of star-fish, and sometimes within the shell of the pearl-oyster. Occasionally the pearl-oyster gets its revenge and buries the young in a mother-of-pearl tomb. They are said to be harmless, and they protrude their head through the posterior end of their host and do not apparently feed upon the juices of the latter. Some authorities, however, regard the larval form of *Encheliophis* as a true parasite, feeding on the viscera of the Holothurian in which it lives. One other European species of fish is regarded as a true parasite. This is *Rhodeus*, known as the bitterling of Central Europe. The female, by means of a large ovipositor, deposits her eggs amongst the gills of fresh-water mussels. These eggs are fertilized by spermatozoa of the male swept in with the breathing or the food current of the bivalve, and they complete their development surrounded by the filaments of the gills. The female ovipositor is nearly as long as the fish itself, and the eggs it lays are remarkably large. The larvæ live in the mollusc for about a month and escape as young fish 10 or 11 mm. in length. But the mussels—at least fresh-water mussels—have their revenge on fishes, as we have seen above. A curiously modified form of Silurid fish is the *Stegophilus*, which is allied to one of the most dangerous fish of the Amazons. For the latter infests in the urethra of people bathing, and it is impossible to extract it owing to the erectile spines which are its gill-covers. The *Stegophilus*, parasite-like, has lost its colour, it is some 30 or 40 mm. long, and lives parasitically in the gill-cavities of a large cat-fish. It has been known to suck the blood in the gills of its host, which attains a very considerable size, being six feet in length.

The marine fish known as the hagfish, belonging to the same group as the lamprey, is semi-parasitic. It burrows its way into the bodies of bony fishes such as the cod, and apparently consumes their muscles.

CONCLUSION

In the evolution of parasites we have to consider, first of all, the starting-point, and then the end. What sort of animal was the parasite before it adopted its deplorably lazy and ignoble habit of life? And we have to consider what is the end factor of this evolution; what, in fact, is the perfect parasite. Now in speculations of this kind we may get some idea of the original form from which the parasite has descended by the consideration of its nearest allies, those which have maintained an independent, active existence. In the case of the flat-worms we can find the first traces of parasitism in the active, free-swimming Turbellaria, with their eyes often quite numerous and of a fair complexity, a nervous system adequate to the needs of the animal, and many of them highly coloured. A very few of these become parasitic, but the group is, on the whole, free-swimming, and aquatic, searching for food and enjoying the sun. When we come to the Trematoda we shall find that there is little or nothing to distinguish them from the parasitic Turbellaria except the absence of motor organs, *i.e.* cilia, and the loss of sense-organs and colour. From the Trematoda we can pass to the unsegmented Cestoda with hardly a break, and from them to the segmented tapeworms, which are amongst the most complete forms of parasite we know.

Another way of orientating ourselves with regard to the evolution of the parasite is to consider its larval forms. In some cases they give little or no help; but in a very large number of cases we can trace the parasite passing from a free-living, happy, independent existence, which it leads in its younger stages, to a slow deterioration by evolution into an unsightly and unwholesome adult. In the Crustacea, especially, we can trace the parasites from the free-living nauplius and cypris forms, busy, bustling about in the sea or fresh water, enjoying life and leading a cheerful, healthful existence with plenty of exercise. These, when they adopt the parasitic habit of life, lose all their activity and come to rest in or on the body of some host. External parasites maintain to a certain extent their mobility, but internal ones become more or less motionless as they evolve further and further towards the perfect parasite, and they lose many and various organs. Having no need to move, their organs of locomotion disappear and their muscles are reduced to a minimum. Living as they do for the most part in the dark, they lose all colour and assume an unwholesome pallor. Surrounded as they can be by already elaborated and digested fluids of their host, they have no need to capture prey. The pleasure of the chase is denied them. In the more perfect cases the alimentary canal has entirely disappeared, and they live on such fluid-food as they absorb through their skin into their bodies. Their metabolism is low. They have no need to keep up a high temperature, for they adopt the temperature of their host. When they have once got to the place they wish to be in they frequently develop organs for anchoring themselves, for the most part hooks or suckers. Those that live on the body of their host frequently develop piercing organs and a sucking pharynx, by means of which blood and other fluids may be pumped into their own body.

Their chances of hitting the right host are small. Where the free-living Crustacea and insects have the whole ocean or the air to live in, they have to hit a particular species, and there are far more misses than hits. Hence everything is done to increase the reproductive activity. Millions of ova are fertilised, and in many cases the egg gives rise to a larva which by budding or dividing still further increases the ultimate number of the adults.

In the case of the guinea-worm millions of larvæ pass out from the body, usually the ankle, of the infected man, into the water. They are swallowed by a small water-flea or crustacean known as *Cyclops*, which in its turn is swallowed by man drinking unfiltered water. The young larva in the body of the *Cyclops* then grows up to form a guinea-worm, which may be six feet long and infests the lymphatic gland of man. It is a common case of "parasites lost and regained." In other cases the larvæ are active and force their own way into the body. And here the larvæ play a great part in disseminating the parasites. The sexual organs dominate the body, and one finds a great many arrangements for aiding the spermatozoa to arrive at the ova. Many parasites become hermaphrodite;

others are parthenogenetic. Sometimes, as in the Crustacea, the pairing takes place at an early age, after which the male disappears and the female becomes parasitic. Animals may be parasitic only in the adult stage, like fish-lice ; or, again, only when they are young, as in the Glochidia, the larva of the fresh-water mussel ; or in the well-known hair-worms, which live in many insects but get into the water before pairing. Or the whole life may be passed in one host, as, for instance, the itch-mite, *Sarcoptes* ; or in two hosts, as in the malarial parasite, which never in any circumstances finds a place in the sun, but leads its whole existence either in man or in a mosquito. The life-histories of parasites often become extraordinarily complicated, and they may lead to the ideal stage, which in bi-sexual parasites is a short-lived, generally dwarfed, male, associated with a bulky female which is nothing more or less than a sac of eggs.

There are a few groups of animals which never become parasitic on others. These include the Protochordata, which are the somewhat degenerate forerunners of the Vertebrates ; the Echinodermata or star-fish and sea-urchins ; and Brachiopoda or lamp-shells, and the encrusting organisms known as Polyzoa. In other groups parasitism is rare. This is so in the Mollusca, the Annelids (worms) and the Cœlenterata (jelly-fish) and it is very rare amongst Vertebrates. The Crustacea, the Insects, Mites, and Protozoa are frequently parasites, and the Flat-worms and Nematoda are almost exclusively so. There is practically no animal immune from parasites, and it is quite possible that the number of parasites is not greatly inferior to the number of all the other animals added together.

THE INDUSTRIAL MEASUREMENT OF COLOUR

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There is one direction in which trained scientific attention is highly necessary, to aid industrial methods. It is, indeed, somewhat surprising that a more sustained attack has not been made on the subject, even though it is one that is full of difficulties. We urgently need a fairly simple, convenient, and not too intricate method of estimating colour for industrial purposes. It is necessary that we should be able to have an exact symbolic equivalent for any colour, in the same way that we have such symbols for so many of our other industrial activities.

The whole range of industry deals with materials, in terms of form as related to function of the objects being made, and in which colour is frequently a prime consideration. Many industries, if they were denuded of all colour, could no longer exist, among them the great decorative textile factories. Despite this importance, such industries have no simple comparative means for measuring colour, and nothing but the scientifically crude method of submitting an actual sample is capable of securing accuracy in giving commercial information regarding colour. It is true that the solar and many other gaseous spectra have been measured and mapped with extreme accuracy, but no industrial relation has been established between this phase of chromatic research and the general measurement of colour for international use in manufacture.

It is entirely necessary to possess the knowledge of standards of linear and mass measurement, together with a developed system of using such standards, before the concept of modern industry can be grasped. It is essentially dependent on the primary factor of the applied measurement of form, capable of being accurately done with a simple instrument, from a foot rule to a micrometer, by an ordinary workman. If exact measurement (industrially speaking, of course) could only be

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established in the laboratory, the construction, for example, of modern motors would be impracticable, and impossible on any commercial scale.

If we now reverse the argument, and apply it to colour, we shall easily admit that if we could establish a similar degree of industrial accuracy in the measurement and nomenclature of colour, we should rapidly render possible a vast advance in the industrial use of colour. Were formal measurement as empirical as colour measurement now is, we should not have advanced beyond the middle ages, when exact linear accuracy was a matter of hand and eye unaided, except by crude implements.

The decorative and textile trades, which in both England and the United States are among the largest industries of those countries, are the only great trades in the world which possess no accurate and generally known international standards for the complete description of their raw material or their finished products. This defect is shared in common with other branches of industry which deal in colour, as pigments or coloured goods, and marks a very serious deficiency that will at no distant date compel attention from the various organised federations of manufacturers in all civilised countries. It is but the plain fact that both national and world trade is seriously hampered in the absence of an international colour standard. Colour in its various manifestations, whether intricate, as in design, or relatively simple, as paint, or in self-coloured piece goods, is one of the prime selling factors in the decorative trades. Owing to the singular poverty of language relating to colour and the absence of complete scientific approach to the problems involved, we cannot yet correctly describe or even indicate accurately the simplest colour in writing. Robert Louis Stevenson, a master in words, was baulked by the attempt to describe a certain shade of red fabric, and gave up the task in despair, while other writers, such as Wilde, have utilised the difficulties of colour nomenclature as a peg for rhapsodical paragraphs ; even then these practised writers fall short of such accuracy of description as would please a really definite thinker.

Colour cannot be described in any word language ; it can, at best, be indicated by analogy and comparison, in terms which are essentially an appeal to experience. A fair subject of comparison with colour is music, which cannot be fully described in verbal language, yet music has a definite system of visible symbols which may easily be written down on paper, or even telegraphed if urgent, and thus transported from place to place, which can then be correctly interpreted by those who have troubled to acquire a modicum of technical manipulative skill.

To any advocate of such a task as that of inaugurating a standard for the classification of colour, great in itself, and yet of infinitely greater value when accomplished, come many questions and many objections. Is it desirable and practicable? is it likely to prove more costly to make than it may be worth? is it possible to be easily workable in everyday use?—these are some of the score of questions. There are also many objections, some of which are reasonable: "Manufacturers will not be bound by such standards"; "such a system would be arbitrary"; "it would cramp design and kill artistic originality"; "it would retard the invention and production of new colours"; "so many colours are required that it would be unwieldy and impossible to work." Such are a few of the questions and objections that must be met and disposed of before such a worldwide system of colour notation, as it is now proposed by the present writer, can even be considered.

Surely if all the multitude of forms existent and possible can be measured, then colour can by some means be measured with at least equal facility and accuracy. We need not here consider the various phases of modern scientific detail necessary to a thorough study of the physical origin of colour, and the way it is developed from the peculiarities of atomic structures and their harmonising and contrasting with the beats of the luminiferous ether, interesting as these studies undoubtedly are. We need no microscope to use a foot rule, nor shall we require optical magnification to measure colour for the use of the normal vision of ordinary people in the everyday world of industry and commerce.

There exists, not only in Britain but in other countries, a vast number of greatly varying local standards of measurement of length, weight, and volume. It is realised by economists that this tends to restrict trade, in a similar way as the lack of verbal language also tends to hamper trade. If the margin of profit be small, and the difficulties of transaction are lengthy and therefore, often, unproductive, as they must be in such circumstances, then such trade will tend to diminish.

Communal agreement, marked by the legal setting up of certain convenient but arbitrary standards, has removed national troubles by the imposition of a regular and known standard. The local ones in many places remain, but always have a definite relation to the national standard, and are capable of translation to it in terms of the national standard. The current system of monetary exchange between various countries is a good example of a standard, in itself obviously flexible, but with international relative scales that are also capable of variation.

We need an analogous system with regard to colour. We find in existence a large number of varying and local standards in which the same name is given to quite different shades and tints. There are in fact more differences between the range of shades and tints known under one generic colour term, such as red, than there are known under any one generic term of length, such as the mile. With colour, these names and colours are associated not so much by localities but by manufacturers, who produce coloured materials of some kind which need definition. In the absence of a national and international standard and agreement, they do their best, individually. They cause immense confusion, just as it would be caused if each maker of machinery had his own standard of linear measurement.

It is not necessary to abolish or to change a single local colour-name ; all that we require to know is its relation to the central national standard. This is easy to determine as soon as such a standard is set up and agreed upon. It is not necessary to invent any new colour-names, any more than it has been found necessary to invent new length-names. Even the metric system, the one most artificially set up, is condensed to as few verbal terms as possible, all of which terms also have their philological relation.

Let us face the many difficulties that arise, and endeavour to define and solve each side of the twin problems of standardisation and classification. First of all, what is a standard ? It is a purely human mental convention, of an entirely arbitrary nature, which science has first obtained empirically and later fixed scientifically, to provide a symbol of rigid fixity by means of which all materials with which humanity deals may be brought against a fixed standard and measured off accurately. All human standards are essentially related to the human body, to which the first unit of any standard must be reasonably proportionate. The English standard unit of length may be considered to be either the inch, the foot, or the yard ; all of which lengths may be measured with the unaided normal eye in a single act. The divisions into thousandths of an inch, which have arisen in recent engineering practice, require mechanical aid for their detection and reading, while the multiplications of the unit, such as the mile, also require extraneous aid to measure, either in actual repeated measurement of the unit or by surveying calculations. Nevertheless, both these extremes of linear measurement are related to the essentially central human standard. The same is true of measurements of volume. While those centrally situated standards are admittedly arbitrary, they are incontestably convenient. When they were first invented, the lack of tools of precision rendered extremely accurate measurement of any kind impossible, although artistic wonders were certainly performed, such as the repeated carving of the marble mouldings of the Parthenon, which would be highly creditable with modern tools and workmanship. At this period tools of measurement were not standardised with any great accuracy, nor were they identical over very large areas of country. When modern science developed, the demand for very accurate standards of reference compelled scientific inventors to take all possible precautions to obtain and maintain reliable standards. Thus the "standard yard" is now kept by the authorities of the Crown, in England, and is a bar of bronze with two platinum plugs set in it with their centres exactly 36 inches apart, from point to point. It is further stipulated that all measurements taken from it for the use of manufacturers must be made at the temperature of 65 degrees Fahrenheit as the length of a metal rod alters with its temperature. Thus a national standard that was the growth of centuries was eventually fixed quite arbitrarily; and as a direct result, there were made possible the beautiful engines and other mechanical inventions whose very production depends upon the closest precision of measurement. But the same results would be just as possible if the yard was made half an inch longer, for the actual length is immaterial, and it is the standard alone that matters. The metre is several inches longer, but is equally useful as a standard. It provides a fixed ratio, known to and agreed upon by a community for comparison of the unknown with the known. It is only because this convention is generally accepted, however, that it is generally usable. The smaller the number of different measuring units there are in use for any specified industrial purpose, the more easily can manufacture and commerce be carried on, and satisfactory results can be reached more quickly.

If it took civilised nations so long to reach even national standards of length and volume, for the measurement of tangible things, how long will it require before we can obtain a standard for such an elusive quality as colour? For as colour has obviously a far more ephemeral value than form, how is it to be measured? This may be answered in two ways; there are many things which have relatively permanent colour, and many forms that are measured that are in fact far less permanent. The thinness of a soap bubble has been measured, and also the speed of a rifle bullet, and the speed of light from which colours arise. Many attempts have already been made, having different systems as their basis, to provide a nucleus of a series of standardised colours, but have, unfortunately, failed, owing to their having been formulated on the wrong principles.

The painters of the Italian Renaissance used to agree to very strict specifications about their colours, for their patrons held them closely to their contracts. But their colours were comparatively few in number and the specification applied to pigments and media, and not to the actual hues. The same accuracy may be seen in other directions in modern times, but does not help to solve the difficulty of colour standards. One of the earliest attempts—if not the first—was that of the French *Société de Chrysanthémistes*, who arranged a classified series of 365 coloured plates relating to foliage, flowers, and fruits. Each of the plates contained four different graduated colours, having each separate colour and tint named in four languages. Another excellent result was achieved by Dr. Robert Ridgeway, the curator of the Natural History Museum at Washington, D.C., U.S.A., who published an interesting volume dealing with classified colours relating to natural history in general. In meeting the difficulty of obtaining accurate results from any printing process, he had the pigments washed on by hand in a kind of tempera colour, and added instructions that the plates were to be exposed to the light as little as possible. This method of producing pigmentary colour was followed by the Prang Company of New York, when publishing their books on art education, which are used in American schools. These colour charts are confined to a comparatively small number of hues, and do not profess to do more than teach a working theory of colour for painting.

In like manner, the colour cards, usually specimens of actual textile fabrics, or of decorative pigments, issued by various manufacturers, do not purport to offer more than the specific range of colours which they can actually offer in goods of their own manufacture, even though they are, in fact, remarkably extensive in the variety of colours, tints, and shades now produced. It is not, however, on these lines that a scientific scale of colour can be formulated, any more than a scale of measurement could be obtained by making a large number of measuring sticks of all possible lengths which might be required, or of making vessels of all sizes to regulate exactly, each in themselves, a million different quantities. Quite apart from the fact that printing ink or paint of any kind must inevitably fade and change its colour, such a system would be too unwieldy, for to elaborate these colour plates to number a million would in truth become a nightmare, which needs but suggesting to prove its unpractical nature. What is really required is an optical " foot-rule," which can be taken about where it is wanted, and applied to any colour, which can then be accurately gauged, and written down in a symbolic rotation.

Fortunately, we have, through the genius of an Englishman, such an instrument actually now available. The " Tintometer " was invented by the late J. W. Lovibond, who was a brewer, to aid himself in the work of brewing. The qualities of different brews are estimated by the colours. The instrument is quite simple, like many other great ideas. It consists of a framework which supports pieces of coloured glass through which the eye looks, and beside which the subject to be gauged is placed. By means of the combination and permutation of several coloured glasses put together an exact match is quickly obtained; the numbers of the glasses are noted, and any future subject of manufacture is tested by the same set of coloured glasses. A greater measure of accuracy in the testing of the quality in organic substances is got by this means than by any other way at present known to the writer. The Tintometer is useful only for objective material, and cannot be used, for instance, for gauging the colour of bright light, any more than gas can be weighed in gravity scales. By means of utilising the art of the modern glassmaker, in glass of differing shades and colours, as many as two million tints could be obtained in strict gradation. This number should prove more than sufficient for all the practical purposes of most industries for centuries to come.

At first glance it seems advisable to make use of the solar spectrum as a basis of standardisation, but further examination proves the impracticability of relying on this spectrum alone for comparison. In the first place, it does not contain all the colours normally known, the red-purples being absent. Also, its colours vary greatly in intensity, and it is even possible to produce some artificial colours which are more luminous than the analogous hues of this spectrum. Although these deficiencies preclude the solar spectrum being used as a standard, it is none the less valuable, and it is advisable to use as the basis of classification, for it gives us the key to the natural scale of colour, upon which we cannot improve.

It is obvious that such a huge number of possible colours and shades demands some ready and accurate means of reference which is an essential factor in the commercial use of a colour standard scheme. There is little value in a colour standard which is clumsy and ponderous, which is not clear to average intelligence, or not instantly available. The answer to this demand also lies near to hand, in the Dewey system of decimal classification. This method allied to the Tintometer glasses, based on the natural order of colours in the solar spectrum, and subdivided above and below the centre or numeral unit of each full colour, according to tint or shade, will amply provide for a classification of even 2,000,000 colours, although ten thousand or less will probably be ample for all practical purposes. Possibly a glance at Mendeleef's *Periodical Table of the Elements* would also be of assistance here, in relating the properties of various colours to an index.

An objection is, that regarding the possible difficulty of working and matching to such fine limits. War-time experience of work in engineering shops, and the successful employment of female labour for precision gauging and other work of fine dimensions, should go far to remove doubts as to the limits of working possibilities in colour. In colour-gauging, the manufacturer will not lose sight of the physiological fact that women are normally better suited for colour work than the average man, for defective colour vision is less prevalent in the female eye.

One objection is always brought by both artistic and pseudo-artistic people ; they assert, immediately they hear of an attempt to standardise colour, that it will " cramp originality." They see to some extent that it is arbitrary, and on that fact hurriedly base their opposition. It *is* arbitrary, it cannot be denied. So is language arbitrary ; so also is all picture-making conventional and arbitrary, for this is the representation of three dimensions in terms of only two dimensions. It is these arbitrary limitations, when recognised and turned to account, which alone make art possible. Modern music, even more than ancient or Eastern music, is arbitrary. It is played with regular and arbitrary intervals, if the instrument is tuned to the so-called " chromatic scale." It is written down in black and white dots and lines, in a symbolism of its own, expressly invented and used for musical notation. But he would be a bold composer who dared to complain that such primary necessities of scales and notation —his system of musical standardisation and classification— " cramped his art," or prevented his musical genius from gaining expression ! He would be a strange architect who complained of the necessity of working with a standard unit of measurement for his buildings. All arts are, in fact, born of their restrictions, and the better these are known and realised by the user, the better is the production, decorative art being no exception. If Science is able to classify and systematically arrange the vast realm of colour only the incompetents will be heard to complain against these limitations. A sound scientific objection may be raised against the attempt to measure all colour industrially, in this manner. The method is not competent to measure highly luminous colour, brighter than the standard of the selected white powder which is now used as a basis of comparison. Nor is it possible to estimate with accuracy the subtle colours of bright light, although developments have been made in the estimation of glowing objects for the purpose of tempering metals.

As all of these modes of chromatic measurement depend upon the eye for final judgment, however, we can utilise any other instrument for the estimation of colour degrees above the line of reflection, to colour originating from a light source, or from a point of reflection so luminous that the ordinary method of comparison by glass fails to provide a high enough standard. We can probably adopt an efficient form of photometer, although this instrument is doubtless only in its early stages. But it is being used by illuminating engineers, and it provides results of a degree of accuracy of about the same order as swift measurement with a foot rule or a tape, over, say, a standard of timber, will enable an experienced eye to calculate the entire bulk with ease. If we can obtain a standard of comparison for reflected colour and for original colour, simple to use in ordinary industrial application, and capable of reasonable accuracy, then we shall be able to make a very definite advance in the general industrial application of systematic colour, by its use in relation to all material objects.

With a system of colour numeration established, the addition of colour-names already known, whether generic names embedded in the language or " fancy names " recently invented, would be technically easy, but perhaps somewhat difficult owing to the probabilities of disagreement, in the earliest stages, at all events, to decide what exact relation a particular name may have to a particular colour.

There is also the adjustment of colour-names in all the different languages of the more important nations to be carefully considered, but all these ancillary problems could quite feasibly be settled by a committee of colour experts, philological experts, and trade experts in friendly conference around a table. The international aspect is already solved in an analogous question—that of codified languages. The dots and dashes of the Morse code, a single series used internationally in wireless telegraphy, have already been arranged by the Marconi Company into a parallel series, covering nine different words or series of words, in as many languages, each of which is exactly equivalent to one definitely fixed and unchanging series of Morse dots and dashes, so that nine different words all have the same telegraphic basis. Quite obviously the same thing can be done with the Dewey numeration of colour, when once established, although many colour numbers will be without names, just as many of the smaller and more distant stars are nameless and are known merely by number or letter. When colour is properly classified in standard numerations, it will be possible to order coloured goods by cable and receive exactly what is wanted, and not lapse into a mere haphazard guess which may more probably be wrong than right. We shall see the disappearance of the vast confusion that now inevitably arises when commercial colour questions are discussed. There are thousands of colours with millions of names which are far too easily interchangeable! There are even more names than things; there are more aspects of things than there are names, and colour is an aspect or a quality of a thing.

The question then arises: "How will the initial standards be arrived at?" As colours apparently change under very slight differences of light; as various eyes appear to "see" colour slightly differently; as a satisfactory set of permanent colours is not easy to secure, how are all these formidable difficulties to be overcome?

It is advisable to state which factors of colour must be fixed in arbitrary fashion to allow of a standard of industrial measurement, though it may be possible to fix them very closely indeed to scientific truth.

Colour is one of the functions of solar (or other) light-energy produced by the resistance of matter, in relation to that matter, essentially dual in origin, and strictly relative to human vision. It displays three principal qualities, in two variables, which produce a third variable. These are:

(1) *Brilliance, or Tone*—the quality of light-dark (luminosity).
(2) *Hue, or Chroma*—the essential quality of colour.
(3) *Saturation*—the optimum of (1) and (2) combined.

In the six principal colours the maximum saturation or point of intensity occurs once in each colour (or blend between colours) and in each colour at a different point relative to tone.

Alteration in (1) decreases saturation, by (*a*) decrease of luminosity, or (*b*) by increase of luminosity; that is, towards dark or light respectively. Alteration in (2) changes the hue towards the next hue on either side, and loses in saturation or intensity if luminosity does not also alter to the optimum of the hue which is being approached. The characteristic saturation point of each spectral hue is analogous to the critical temperature of liquid-solid.

It is necessary to fix the standard six points, together with the two ends of the visible spectrum, providing either six or eight standard points, in terms of three variables, which will then produce a standard no longer variable.

The interaction of the variable phases of energy which produce colour in natural light may be observed at different times in the sky. One of the most common and frequent effects produces the three principal different colours of sunlight, airlight, and cloudlight, all of which are familiar in England, in varying degrees, almost every day.

The observation of the hues of coloured objects is thus made difficult both by natural and by artificial light, both of which are susceptible to change, the latter being perhaps more completely under control. The direct sunlight at midday ranges from white to yellow, down to the orange and red of dusk or misty conditions. The refracted light from the atmosphere at midday has a distinct blue hue, and under the term " north-light " has been more or less accepted as the standard for " artificial daylight." Nevertheless, the natural north-light varies considerably in time and place, differing on sea or on land, in city or country. Diffused sunlight or airlight through aqueous vapour at midday produces the whitest known light, as cloudlight, but it is more frequently seen as a grey tone to a tone approaching black. The combined light from these three sources is the " natural light," most frequent in England. In India the third condition is absent for two-thirds of the year, and the general light is much more vivid, and colours appear more saturated; but, as the intensity of all of them increases in proportion, the total result is but little different.

Besides the standards of colour, therefore, it is necessary to provide standard lighting by which to view selected colours, and it may prove necessary to utilise artificial light for general practice owing to the difficulty of ensuring regular natural conditions.

A small committee of experts, whose own colour vision has been extensively tested and found accurate, should examine the first standard colours in a specified light, say, at mid-day under a cloudless sky, in a north light, possibly even on a specified day of the year. These standard colours should be obtained in various chemical solutions or solid minerals of extreme purity, of permanent colour, and of known quality and quantity. From these scientifically accurate chemical or other solutions the coloured glasses for the standard colours should be selected and adjusted by experts, and in between these the ratio of other shades and tints would be mathematically fixed by the decimal numeration. The coloured glass would always be made with reference and in chromatic relation to the hue of a specified chemical liquid, and not from matching other coloured glass, which method would secure a central permanent standard known to all, and verifiable at pleasure by any one who cared to take the trouble.

Having traversed the practical difficulties which are actually to be met with in the establishment of an International Colour Standard Bureau, we may consider other objections of a less restrictive character. It does not seem probable that any manufacturer of decorative materials would doubt the advisability and immense use of such a standard, if it could be set up; he might be more inclined to question the cost. But the maintenance charges of a National Laboratory, employing a small number of assistants under expert control, would be less than the cost of a single efficient laboratory for the manufacture of dyes and pigments. It is even within the bounds of possibility that the scientific investigation of colour along such mathematical and proportional lines might give interesting results in the discovery of new molecular combinations for producing new dyes. But even if the cost reached £10,000 a year, the results would, in five years, be well worth the outlay to the decorative trades of the country.

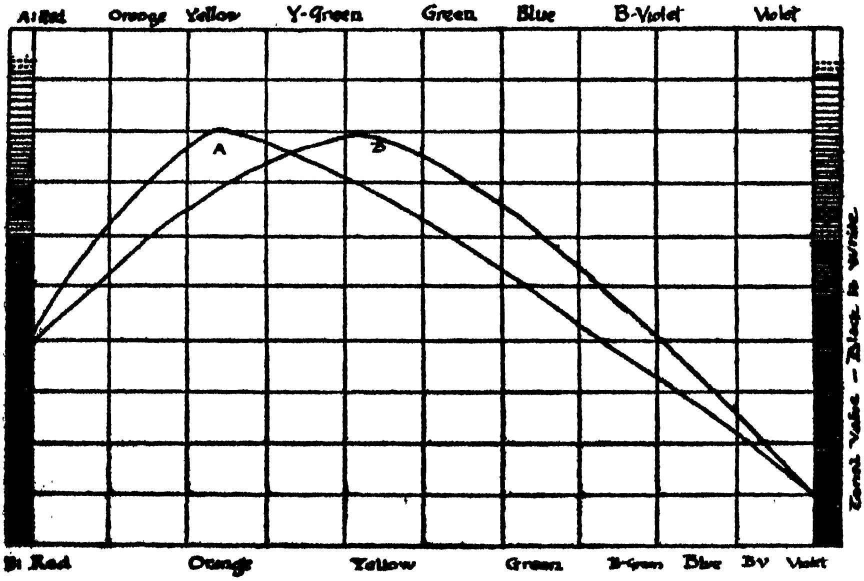

Chart showing approximate curves of saturatisn in relation to tone :
A. Prismatic solar spectrum : B : Diffraction spectrum.

The above graph is an approximate one, relating the curve of saturation to change of hue, and also in relation to tone. Curve A is that of the prismatic solar spectrum, and Curve B is that of the solar spectrum, as shifted by a diffraction grating. No exact measurements are suggested in this graph. It defines colour terminology in some aspects: the curves are those of the greatest saturation. Their vertical rise and fall is that of tone or luminosity, in relation to hue-less black, grey, and white. Their progression laterally is that from hue to hue. It is notable that in this natural spectrum, the tone changes progressively with hue. The ordinary chromatic circle applies to hue only. It arbitrarily states certain facts, and omits others of equal importance. The conclusions drawn from it regarding so-called "primary colours" are not supported by other facts. It would be more correct if drawn as part of a spiral, in terms of wave-length.

Any system of colour measurement must be able accurately to define a colour in terms of hue or chroma, and tone or luminosity. Intensity or vividness appears to be limited to a single curve, in each spectrum, which successfully defines the intersection of each hue at the most definite point, with greatest degree of luminosity possible in each particular colour. Above the curve, towards white or light, each colour fades into *tints*, with increase of luminosity, decrease of hue in chroma, and decrease of saturation. Below each curve, towards black or darkness, each colour merges into *shades*, with decrease of luminosity, decrease of hue in chroma, and decrease of saturation.

The relatively fixed points, judged by visibility, are at the red and violet extremes, with the yellow as a variable factor situated proportionately between. These points vary slightly with different observers, in different circumstances, but they require to be determined arbitrarily for the purpose of a system of measurement. Colour schemes which are founded on this curve of saturation are those which have been found empirically to give the greatest degree of pleasure to the normal eye. It may, therefore, be taken when fully corrected by measurement, as the characteristic curve of current visual value in colour. The right-hand portion is that part which most affects the normal silver salts of the photographic plate, and is largely coincident with the actinic quality of light-rays. The remainder on the left is of course that portion peculiarly associated with heat, as calorific rays of energy. To artists they are generally known as " cold " or " hot " and have been observed by them to be associated with the phenomena of heat, in fires, etc., or in the phenomena of electricity, in light with relatively little heat.

The graph also suggests the relative degree of illumination necessary to obtain equally good visibility when white light is falling on surfaces of the same material of different colours. Colour blindness implies a departure from the normal curve, allowing confusion to occur between two or more points by lack of sufficient emphasis on saturation or chroma perception. Blindness implies a flattening of the curve, usually by raising the base. From the top, it can momentarily occur by excessive luminosity, when both form and colour perception are difficult until adaptation has taken place. All materials under brilliant light, as in the Eastern sunlight, appear to be themselves brilliant, but all maintain relation, and darks are less intense, while lights cause optical fatigue. There thus appear to be two distinct qualities of perceptive ability in the human eye, yet these are not only in terms of colour, but of chroma, saturation, and tone, in different modes of excitation of the whole optical nervous organism, which at their optimum efficiency produce the perception of saturation characteristic of perfect colour vision.

NOTES

Prof. E. W. MacBride, F.R.S.

Those who have followed Prof. E. W. MacBride's numerous articles in SCIENCE PROGRESS and in other periodicals will have been reminded that this worker in the zoological field is probably the most active and stimulating personality in British biology to-day. We may not always agree with Prof. MacBride, but we must admit that the Professor has no equal as a writer of articles which are at once provocative and thoughtful.

In all discussions on Neo-Lamarckism, Prof. MacBride has taken a leading, and we think a convincing, part. The present writer, from the cytological side, has constantly been reminded that the opponents of this theory base their statements on evidence which can no longer be upheld. The Weismannian theory of the germ plasm has been so distinctively criticised in recent years by cytologists and embryologists that it can no longer be argued that the germ cells are so isolated and sterilised as has always been urged by Weismannians.

It has always seemed to the writer that the opponents of the Neo-Lamarckian position overlook the fact that changes in the hereditary mechanism of the organism must have taken an immense period of time to appear. Thus there is no good ground for expecting that a chain of experiments in " use and disuse " lines even carried over several years would give sufficiently clear evidence. The out-of-hand condemnations of Lamarckism indulged in by some writers entirely ignore this fact.

Recent Discoveries in Mammalian Reproductory Physiology

The recent work of Allan and Doisy and their associates on ovarian hormones is of a spectacular nature. These observers have isolated from the liquor folliculi of cows and pigs especially a substance which will cause the œstrus changes in spayed rats. It should be noted that the presence of some such hormone in the ovary, separate from the secretion of the corpus luteum, was predicted by Marshall some years before, and its site traced by a series of brilliant experiments to the follicle.

Viennese workers also have for some years experimented with properly extracted ovarian hormones, and the work of Allen and Doisy is not the first of its kind.

An American chemical firm is now engaged in the manufacture of this ovarian hormone, and the extent of its usefulness in gynæcology is yet to be discovered. Probably this hormone will be only one of two or three others yet to be isolated from the ovary. Marshall, one of the foremost living investigators of the œstrus cycle, has predicted that the ovarian hormones will be found to be three—follicular, from corpus luteum, and possibly from interstitial tissue.

On purely histological grounds the writer is doubtful if the so-called interstitial tissue is a factor of any real importance in the ovarian cycle. O'Donoghue denies that interstitial tissue exists in the marsupials he has studied, and so far as the writer is concerned, an extensive investigation into the question of interstitial tissue in the human ovary has convinced him that no such regular and distinct tissue exists. In certain of the lower placentals it is true that there are chains of peculiar "interstitial" cells, but these appear to be "disappointed follicle cells," and nothing more.

In all probability it may be found that the corpus luteum contains more than one active substance, and if this is so, much of the contradictory evidence regarding the physiological function of this organ may be explained.

For years gynæcologists have been in the habit of administering dry extracts of corpus luteum, by the mouth, and in large quantities. This is said to be successful in certain forms of sterility. There are several difficulties in the way leading to an understanding of this effect, if it is really physiological and not mental.

The South African Association for the Advancement of Science (Oudtshoorn Meeting, July 6–11)

This Association held its annual meeting—the twenty-third in its history—at Oudtshoorn, under the presidency of General Smuts. Eighty papers in all were read, and a very successful meeting was the result: it seems strange to read of a politician and soldier giving a presidential address to a scientific association, especially of the type which was delivered by General Smuts, for the address was both learned and original. General Smuts discussed both flora and fauna of South Africa, the Wegener hypothesis, meteorology and climatology, and ended up with a plea for Government recognition of research.

In the Zoological Section, Dr. Duerden, Dr. Annie Porter, Dr. Fanthenn and Dr. Warren were prominent, the latter bringing forward his results on spider spermatozenesis.

The Anatomical and Ethnological Sections were particularly interesting, Dr. Raymond Dart contributing several valuable papers.

The South African biologist, anatomist, or ethnologist has a field which must ever be the envy of European workers, and the Report of the South African Association demonstrates that the searchers are worthy of the field.

We think, however, that more attention might be paid to Marine Biology in the Southern Seas.

The Optical Convention, 1926

Very notable advances have been made in Optical Science and in the Optical Industry in Great Britain since the last Optical Convention was held in 1912, especially during and since the war, as a result of which it is claimed that this country has gone far to regain its old position of leadership. Progress in every direction has probably been much more rapid than in any previous period. There is ample evidence that the difference between the present position of Optics in this country and that before the war is not generally realised. No coherent presentation of what has been accomplished has yet been attempted, and the time seems ripe for a general review. It was, therefore, decided by some of the Societies concerned that another convention should be arranged in 1926. This Convention will meet at the Imperial College of Science and Technology, South Kensington, during the week of April 12–17, inclusive, under the presidency of the Astronomer Royal, Sir Frank Dyson, M.A., LL.D., F.R.S.

The chief object of the Convention is to discuss British contributions to Optics in recent years, and the industrial section of the Exhibition will be confined to British manufactures. The programme includes an address by the President, meetings for the reading and discussion of a large number of papers on optical subjects, which have been promised, and a series of lectures of a popular character.

The Exhibition is to be in three sections, including (1) exhibits of an experimental or research character, (2) instruments of historic interest, and (3) the commercial section, including exhibits by British manufacturing firms in all branches of the optical trade.

A special Entertainments Section is being arranged with the co-operation of Captain Clive Maskelyne, of St. George's Hall, and of the Director and students of the Royal Academy of Dramatic Art, in which dramatic performances, incorporating various interesting optical illusions, are being specially composed for presentation at the Convention.

In conformity with the previous Conventions, the principal publications will be: (1) *The Proceedings.* This volume will give a record of the scientific proceedings of the Convention, including the presidential address and the papers read at the meetings, with a report of the discussions. (2) *The Catalogue,* a full, illustrated, and descriptive list of the instruments and apparatus shown.

Inquiries as to the privileges and subscriptions for membership should be addressed to the Secretary, The Optical Convention, 1926, 1 Lowther Gardens, Exhibition Road, London, S.W.7.

The American Indian

In the Smithsonian Report for 1923 Dr. Arles Hrdlicka gives a critical discussion of the probable origin and antiquity of the aboriginal population of America. First, by considering the language, culture, mentality, constitution, and physical characteristics of the Indian peoples, he concludes that they may all be traced back to some common race, different branches of which may have spread to the American Continent at widely distributed periods of time. He next considers their antiquity. Here the evidence is of two kinds direct—the complete absence of any human remains of geologic antiquity in the continent, and indirect—the American Indian closely resembles the rest of mankind, and hence probably has the same ultimate origin. The conclusion is that the duration of his habitation is to be measured in thousands of years rather than tens of thousands. As to the origin of the Indian peoples Dr. Hrdlička concludes that they came from Asia via the Bering Straits or the Aleutian Islands. They have little in common with the negro, but the " physical resemblances between some members of the Asiatic groups and the average American Indian are such that if a member of one or the other were transplanted, and his body and hair dressed like those of the tribe in the midst of which he was placed, he could not possibly be distinguished physically by any means at the command of even a scientific observer."

For various reasons discussed at length in his paper the author considers that the Asiatic invasion of the New World did not begin before the European late Palæolithic or earlier Neolithic period. The first subtype to arrive was probably dolichocephalic, and is represented to-day by the Algonquian, Iroquois, Siouan and Shoshonean stocks in North America, by the Piman Aztec tribes farther south and by many other branches along the coast of South America from Venezuela to Tierra del Fuego. Next came the Toltec type, marked by brachycephaly, which settled along the north-west coast, in the central and eastern mound region, the Antilles, Mexico, and over much of Central America and Peru. Then, when the land was already well inhabited, came the Athapascan Indians, to which type belong the Apache, and lastly the Eskimo.

The Prickly Pear in Australia

One of the most urgent problems facing the Australian Institute of Science and Technology when it was first formed was the problem of the prickly pear. In a Report published by the Institute in 1919 it was stated that the plant had spread over twenty-three million acres and that it was spreading at the rate of one million acres each year. A scheme for the investigation of the insects and fungi known to be inimical to it was drawn up and an annual sum totalling £8,000 was granted to the Institute for five years to enable the plans to be carried out.

A Bulletin describing the progress which was made during the period 1920–24 has just been issued, and it enables us to form a very fair idea of the difficulties which the problem has presented. In the first place, it has been necessary to be absolutely sure that any insect or disease introduced into the continent to destroy the pear should not also destroy the rest of the vegetation! Various insects and fungi had to be studied in their habitats in North and South America; means for transporting them to Australia had to be devised, and their effects, not merely on the pear but on sixty other kinds of vegetation (cereals, fodder plants, fruit-trees, and timber), have required most careful examination. Furthermore, the utmost care has been taken that none of the known enemies of the insects themselves should be introduced with them.

As a result of all this work three strains of the cochineal, *Dactylopius tomentosus*, and the moth, *Melitora junctolineella*, have been liberated and there is every reason to believe that the combined attack of these and other enemies of the pear will, in time, liberate Australia from the worst weed-pest that has established itself in any country in the world.

Winter Thunderstorms

In December 1924 Mr. S. Morris Bower, F.R.Met. Soc., made an appeal through the Press for information regarding thunderstorms occurring in the British Isles between January 1 and March 1, 1925. The reports received by him may be summarised as follows :

1925.	England and Wales.	Scotland.	Ireland.	British Isles.
January . .	10	12	10	17
February . .	20	10	8	23
March . .	16	5	4	17
Total . .	46	27	22	57

Analysis of the distribution of these thunderstorms showed that in three areas no storms at all occurred during the three months, namely, a part of the northern counties in England, a large area in Wales, and a belt stretching from East Yorkshire to South-East Wiltshire. The stormiest regions were those near the south coast (specially the southern parts of Surrey and Sussex) and in the central portion of the west coast of Scotland. Mr. Bower circulated a request for reports again this winter, and it will be interesting to see whether the geographical distribution of stormy and stormless areas remains the same.

To Dazzle, or Not to Dazzle

The winter season has produced the usual controversy in the papers devoted to motoring as to whether headlights should or should not be switched off when passing another car, and the arguments used by the supporters of the two policies prove quite conclusively that neither is correct. It is for this reason that, in all probability, the definite ruling as to procedure which both sides demand will not be granted. Meanwhile, in order to minimize the trouble in the United States, the Bureau of Standards has issued a chart suitable for exhibition in public garages, etc., showing how both the bulbs and brackets of headlamps should be adjusted so that the upper limit of the projected beam shall not extend above the level of the top of the lamp. The need for such instructions in the States is shown by the fact that of 400 cars by 58 makers tested by the Bureau only 22 had their headlights correctly adjusted and in good condition. The Report which accompanies the chart states that most of the anti-glare devices which have been put on the market are unsatisfactory and that as a rule they merely reduce the effectiveness of the reflectors in lighting the road. It is considered that, when properly used, the spotlight is a helpful auxiliary to the standard headlight equipment, but this device can only be used in this country at a risk of a police summons under the terms of the antiquated Motor-car Act of 1904.

While this matter is perhaps primarily of interest to the motor user, it is likely that all those who have occasion to use dark country roads or unguarded sea fronts have quite definite views on the subject, and will appreciate the advantage which might accrue from an educative effort in England on the lines of that now being carried out in America.

Motor-tyres and Reclaimed Rubber

The United States Bureau of Standards has carried out tests to determine whether an economic gain would result from the use of reclaimed rubber in tyres, especially when the cost of crude rubber is high. Service tests were made on eighty tyres each of standard four-ply construction, but built up in four sections. These sections consisted of compounds containing respectively 0 per cent., 10 per cent., 18 per cent., and 25 per cent. of reclaimed rubber. As a rule, the tyres were run on rural delivery mail motors and were kept in service until the weakest tread was worn through to the breaker, a process which generally required about 7,000 miles' use. The treads were then removed and a definite length from the centre of each section was examined for wear. The tests showed that the resistance to wear is lowered roughly in proportion to the amount of reclaimed rubber used, the treads containing 25 per cent. reclaimed rubber being about 70 per cent. as good as those containing new rubber only. It is concluded therefore that the advisability of substituting reclaimed rubber for new rubber depends simply on the relative cost of the two materials. The recent outcry in the States over the price of the raw material has, however, shown that its cost to the manufacturer is relatively so small a fraction of the cost of the finished article to the user that it would seem hardly beneficial to either to use the reclaimed product. There are, of course, other rubber products in which the resistance to wear is not of first importance and in which reclaimed rubber may be used as satisfactorily as new rubber.

The Position of Religion and Science in Russia To-day

In Russia, where Bolshevism has held sway now for some years, the old religions have been abolished, and we are informed that modern science is to take their place. Those of us who on weekdays call ourselves " modern scientists " will feel gratified that on Sundays our status soars to the dizzy heights of a High-priesthood. Seriously, however, every student of psychology will watch with much interest this remarkable experiment—for it is an experiment—which the Bolsheviks are carrying out to-day. The religious instinct, if such we may call it, is normally present in all but the lowest grades of savages, and it is doubtful if forceful suppression of such instincts can for long be successful. Sooner or later people will come together secretly in order to carry on religious ceremonies, and brutal treatment of those who are detected carrying on such observances will only fan a flame, which, however small at first, will ultimately burn up those who attempt to extinguish it. Whatever be the position of religion in Russia to-day, it is true that scientific institutions are rapidly beginning to recover their former importance. The writer has, for the past year, been in receipt of a number of important published papers, on cytological and embryological subjects, emanating from Moscow.

The policy of the rulers of Russia is found to modify itself, and to approximate more closely to that found in other European countries.

It is a good sign of a return to sanity of the rulers of Russia when scientific men are encouraged to work under the best conditions.

The fate of many Russian scientific workers, prominent in the old régime, is indeed sad. Both England and America have gained considerably by the influx of certain prominent Russian scientists. One of these—a veteran histologist, Prof. Kulchitzky—recently met his death at University College, London, under tragic circumstances, falling down a lift shaft. Maximow, the well-known histologist, is now in America, while Andrep, one of Pavlov's associates, is at present working at University College, London.

Probably the happiest thing that could happen, not only for these exiles, but for the Russian nation itself, would be for the policy of the Bolsheviks to become so modified as to allow the exiles to return.

Public Discussions on the Ethics of Birth Control

This subject has been much before the public recently, and we have no intention of pursuing the question here and now. While believing firmly in the general necessity for such control, we do not think that any good purpose can be served by the open discussions which the editor of a contemporary has allowed in the columns of his well-known paper.

It should be remembered, and we are remembering this fact now, that certain scientific periodicals are taken in at both boys' and girls' schools, and the discussions in question are not the sort of literature one wants children to read.

We believe that the proper people to teach the subject, where necessary, are medical men, and that discussions by notoriety-mongers in the public periodicals are to be deprecated strongly.

The Harrow School Register (1845-1925)

This is the second series of the *Harrow School Register*, and deals with men of our own generation. Harrow and Eton are the two most exclusive English Public Schools, and naturally one turns the pages of these volumes with interest. Politics appear to have been the field most successfully entered by Harrovians. There are five Harrow old boys in the present Cabinet; and there were two Harrovians in the Labour Government which preceded the present Administration.

During the eighty years included in the present register, nine old Harrovians have become Fellows of the Royal Society.

It would be interesting to have before us the figures of, say, the Manchester Grammar School, or the Blue Coat School, or of Westminster. Much of the success of Harrow men is probably due to the fine start in life which money and influence can provide.

A Herdman Scholarship

Relatives and friends of the late Sir William A. Herdman, who died so tragically in a London street, have founded a memorial scholarship at the University of Liverpool. It seems right that the funds of the scholarship should be devoted to research on marine zoology, in memory of one of the greatest exponents of this subject.

At Liverpool there exists one of the finest Zoological and Oceanographical Departments in Europe, and the student who wins one of these scholarships will be enabled to carry out the study of marine zoology under the best conditions. Applications for the Herdman Scholarship should be made to the Registrar of the University of Liverpool before the first day of the summer term.

England and Ireland

English scientific men who have visited Ireland since the Treaty have been agreeably surprised at the courtesy and warmth of the welcome they have received from those at present in power in Ireland.

On request the Irish Customs Authorities have passed all luggage without examination, and have done everything in their power to make the visitors feel that their presence is appreciated. This is undoubtedly the spirit with which Englishmen will be met in any part of Ireland.

It is unfortunate therefore that there should exist in the minds of any Englishmen a suspicion that things English are being deliberately boycotted by any important section of Irishmen. This is not so. The present Administration in Ireland has not a completely free hand, and there can be no doubt that were they not embarrassed by a certain section of malcontents, many things which puzzle the Englishman would not occur.

Notes and News

The New Year Honours List contains the following names well known in scientific circles : *K.C.M.G.*, Prof. M. W. MacCallum, Vice-Chancellor of the University of Sydney. *Knights :*

Prof. T. Hudson Beare, Regius Professor of Engineering in the University of Edinburgh; Prof. J. B. Farmer, Professor of Botany at the Imperial College of Science, South Kensington; Mr. P. J. Hartog, Vice-Chancellor of the University of Dacca.

The President and Council of the Royal Society have recommended the following candidates for election into the Society: Dr. J. A. Arkwright, bacteriologist; Dr. E. J. Butler, Director, Imperial Bureau of Mycology; Lieut.-Col. Christophers, Indian Medical Service; Prof. F. J. Cole, Professor of Zoology, University of Reading; Mr. A. C. G. Egerton, Reader in Thermodynamics, University of Oxford; Dr. Ezer Griffiths, Senior Assistant, National Physical Laboratory; Mr. H. B. Hartley, Lecturer in Physical Chemistry, University of Oxford; Dr. H. Hartridge, Lecturer in the Physiology of the Senses, Cambridge; Prof. G. B. Jeffrey, Professor of Pure Mathematics, University College, London; Prof. O. T. Jones, Professor of Geology, University of Manchester; Prof. W. C. Lewis, Professor of Physical Chemistry, University of Liverpool; Prof. E. A. Milne, Professor of Applied Mathematics, University of Manchester; Mr. L. F. Richardson, Honorary Secretary of the Royal Meteorological Society; Mr. H. T. Tizard, Principal Assistant Secretary to the Department of Scientific and Industrial Research; Prof. R. S. Troup, Professor of Forestry, University of Oxford.

The Nobel Prize in Physics for 1924 has been awarded to Prof. K. M. G. Siegbahn, of the University of Upsala, for his work on the measurements of the wave-lengths of X-rays. The prizes in physics and chemistry for 1925 have been reserved. The prize in chemistry for 1924 was again reserved, and in consequence, cannot now be awarded at all. The money available for it has been assigned to the reserve fund of the chemical section of the Nobel Institute.

Sir Robert Hadfield has received the Cross of an Officer of the Legion of Honour from the French Government in recognition of his contributions to the science of metallurgy.

The Gold Medal of the Royal Astronomical Society has been awarded to Prof. Albert Einstein for his relativity theory of gravitation.

The Council of the Institution of Electrical Engineers has made its fifth award of the Faraday Medal to Col. R. E. B. Crompton, honorary member of the Institution.

The Symons Gold Medal of the Royal Meteorological Society has been awarded to Lieut.-Col. Ernest Gold, Assistant Director of the Meteorological Office; the Röntgen Award of the Röntgen Society to Dr. Robert Knox; the Rivers Memorial Medal for anthropological research to Prof. C. G. Seligman for his work in New Guinea, Ceylon, and the Sudan.

The Council of the Geological Society has made the following awards: Wollaston Medal to Dr. Henry Fairfield Osborn; Murchison Medal to Professor W. S. Boulton (Birmingham University); Lyell Medal to Prof. O. T. Jones (Manchester University).

Various scientific societies have elected as their Presidents for the current session the following: Royal Meteorological Society, Sir Gilbert Walker; Royal Astronomical Society, Dr. J. H. Jeans; Royal Microscopical Society, Dr. James A. Murray; Physical Society, Prof. O. W. Richardson; Optical Society, Mr. T. Smith.

We regret to have noted the announcement of the deaths of the following well-known workers in the scientific field during the past quarter: Dame Louisa Aldrich-Blake, Dean of the London School of Medicine for Women; Prof. W. Bateson; Mr. Alfred Bell, geologist; Dr. J. A. Brinell, of hardness test fame; Dr. R. Caton, physiologist; Prof. M. Curry, formerly Professor of Engineering at King's College, London; Prof. C. Gogli, histologist, Mr. W. P. Hiern, F.R.S., botanist; Rev. G. Henslow, botanist; Dr. R. A. Joyner, chemist; Prof. C. C. W. Kilian, geologist; Prof. E. Knecht, technological chemist; Prof. J. N. Langley, physiologist; Mr. J. H. Maiden, F.R.S., lately Director of the Sydney Botanic Gardens; Prof. J. G. M'Kendrick, F.R.S., physiologist; Mr. B. N. Peach, F.R.S., geologist; Prof. Alfred Perot, physicist of the École Polytechnique, Paris.

We learn from *Nature* that the Labour Government of New South Wales has decided to close the long-established State Observatory at Sydney. The site of the Observatory has long been unsatisfactory owing to the growth of the town, and its removal to a distant suburb had been urged on many successive Governments. The action of the Labour Party is nevertheless both surprising and disconcerting. It is considered possible that the Commonwealth authorities will find it desirable to take over control of all the observatories in the continent; they have already assumed responsibility for the meteorological services.

A Bibliography of Bibliographies on Chemistry and Chemical Technology, 1900–24, by Clarence J. West and D. D. Berolzeimer, is announced by the National Research Council, Washington, D.C., as their *Bulletin*, No. 50 (308 pp., $2.50). This work is composed of the following sections: General Bibliographies, Abstract Journals and Year-Books, General Indexes of Serials, Bibliographies of Special Subjects, and Personal Bibliographies. As the title indicates, the work is a compilation of bibliographies published as separates, or at the end of books or magazine articles, or as foot-notes to the same, on the numerous aspects of pure and applied chemistry. Each entry gives name of author or compiler, title, and place of publication. The majority of the entries state the number of references, thus giving an indication of the completeness of the particular bibliography. The entries are classified under the proper subject-headings, alphabetically arranged. The duplication of individual entries has been largely avoided by the liberal use of cross-references. An approximate analysis shows that there are about 2,400 subject headings, 7,500 author entries, and a total of 10,000 individual bibliographies. Although no claim is made for the completeness of the compilation, it is believed that the work will furnish a convenient starting-point for any bibliographic search.

The report of the Ramsay Memorial Trustees for the University year 1924–5 states that there are now eighteen Fellowships administered by the trust. These Fellowships are tenable at any University in the Kingdom, and the details of the work of twenty-two Fellows given in the Report show that very complete use is made of the freedom of choice which is permitted to them. The distribution is as follows: University College, London, 7; University of Cambridge, 4; Davy-Faraday Laboratory, 3; Universities of Oxford and Manchester, 2; of Bristol, Sheffield, King's College, London, and Royal School of Mines, 1 each. The work completed and in progress deals chiefly with organic and physical chemistry. The total annual value of the Fellowships is about £4,600, of which about £3,100 is provided by grants from Dominion and Foreign Sources.

In a note to *Nature* (Jan. 16, 1926) Prof. J. C. McLennan gives the result of a recent survey of the helium resources of Canada carried out by Mr. R. T. Elworthy for the Dominion Mines Branch. It appears that sources of natural gas containing up to 0·1 per cent. of helium are fairly widespread, but that in exceptional cases a considerably greater proportion of helium is present. Thus, in Alberta, a content as high as 0·34 per cent. was found; in Norfolk County there are considerable supplies of gas containing from 0·4 to 0·5 per cent., while in Peel County, at a distance of only thirty-five miles from Toronto, three wells have been sunk which draw, from an horizon 600 feet deep, a natural gas containing rather more than 0·8 per cent. of helium. The Ontario Government has secured these wells for the Crown, and a helium gas extraction station is to be erected. Their supply is not very large, but they are expected to yield at least 100,000 cubic feet of helium per year, whence it is hoped to supply all the helium required for research in Canada and possibly for the rest of the Empire.

The *Report of the Food Investigation Board for 1924*, which has just been published (H.M. Stationery Office, Adastral

House, Kingsway, W.C.2, price 3s. 6d. net.) contains an account of the progress which has been made in the investigations of (a) the theory of freezing, (b) the preservation of eggs, meat, fish, fruit, and vegetables, (c) the chemistry of oils and fats, and (d) the engineering problems of refrigeration. An introduction gives a brief summary of the results which have been obtained expressed in purely scientific language. It would be well if this summary also included some indication of any practical or commercial benefits which have, or which may be, expected to follow.

The research on freezing shows that, in the freezing of tissues, whether of plant or animal origin, there are two kinds of change which require consideration. First, the displacement of the contained water, which may involve a permanent and irreversible change in the microscopic structure; and, secondly, a consequent permanent destruction of the finer molecular structure. Irreversible molecular complexes involving water are formed, and this chemical change cannot be reversed in any simple way by a subsequent rise of temperature.

The work on eggs shows that fertility is retained for the longest period of time if the temperature is maintained between 8° and 10° C. while at temperatures below 0° C. the embryos die rapidly. The statement concerning preservation by freezing is very incomplete, but would appear to indicate that a temperature between $-0{\cdot}65°$ C. (the freezing-point of the yolk) and $-6°$ C. must be maintained. Extensive investigations of the various methods of storing apples are still in progress and the results so far obtained show definitely that the mode of storage must vary with the variety of apple; but in all cases cold storage at 1° C. and "gas" storage at an average temperature of 7° C. were found to give a longer storage life than the usual method. Curiously, too, the storage life depends on the soil in which the trees are grown. Apples from Kent gravel had the longest life, from Lincolnshire silt next, and from Fen soil least. Finally, as an illustration of the complexity of the problem, it may be mentioned that while ordinary storage may prove satisfactory in one season, it is less satisfactory in another; this probably being related to the fact that the destruction of the apple may be brought about by fungi and by internal changes, the seasonal effect being different in the two cases.

The Proceedings of the Physical Society of London for February 1926 (vol. 38, part ii.) contain a most interesting paper by Mr. R. S. Burdon, of the University of Adelaide, entitled, *The Spreading of one Liquid on the Surface of Another.* The spreading of water and water solutions over mercury forms the chief part of the investigation. The purest conductivity water in the presence of air is found to spread very slowly on a clean mercury surface; traces of acid in the water cause the spreading to be much accelerated, while traces of alkali inhibit it altogether. The presence of neutral salts in solution in the water (even the chlorides of silver and mercury) also produce rapid spreading. The greatest difficulty was experienced in obtaining clean mercury; but it was finally discovered that by distilling in a hard glass still in a slow air current, and then shaking thoroughly with a mixture of potassium bichromate and sulphuric acid mercury with a satisfactory surface could be obtained. Such mercury was, however, immediately spoiled by being poured into an ordinary glass dish, unless the latter had received prolonged treatment with chromic acid, and with boiling distilled water. With these precautions it was found that a drop of water would spread over a mercury surface after a previous drop had spread and evaporated. Working with solutions of common salt, it was observed that dust-motes settling on the liquid film immediately commenced to rotate, sometimes very fast, but usually taking 1–2 seconds per rotation.

When a perfectly clean glass dish was rinsed with water, and then held vertically to drain, a well-defined horizontal ridge of water was seen to travel *upwards* across the glass; the ridge being thick enough to distort objects viewed through it and to focus sunlight shining through. Lycopodium dust blown on to the moving ridge served to show that the surface layer of the water film near the ridge is in considerable movement, some of the particles of powder being carried up an inch or more by the ridge in its passage.

We have received a copy of an issue of the *Journal of the Science Association*, India, a quarterly publication edited at the Maharajah's College, Vizianagaram. It contains a number of excellent papers of general interest, and the printing is quite up to European standard. With one exception the papers are written by Indian authors, and we were pleased to note that one at least contained an account of work carried out in a laboratory in Europe. It is an excellent idea to encourage Indians working outside their own country to give an account of their progress in one of their own journals. The exception referred to above is a paper by a German student working in Munich and printed in the German language. The editor knows, without doubt, what will be best appreciated by his readers; but to us the printing of such papers seems inadvisable except they be of classical importance. It should be added that an abstract of the paper, in English, is printed at the end.

The American journal *Popular Astronomy* for November 1925 contains an account of some of the papers read at the thirty-fourth meeting of the American Astronomical Society.

Two of these papers dealt with measurements of the sun's coronal radiation which were made during the eclipse of January 24, 1925. Observations by H. T. Stetson and W. W. Coblentz indicate a large infra-red radiation from the corona, and would lead to the conclusion that its black-body temperature is of the order of 3,000° C.—a figure which the authors of the paper consider may perhaps be somewhat low. They state that " all the radiometric data now published are in agreement in indicating that the corona contains matter in a liquid and perhaps solid state. . . ." The other paper by E. Pettit and S. B. Nicholson gives an account of some photographic observations which indicate that the amount of red light in the coronal spectrum increases from the outer corona towards the limb of the sun and this " is not what one might expect from a theory of solid or liquid particles, since in that case the temperature would be higher near the sun, which would necessitate an excess of blue light." This number of the journal also contains a warm appreciation of the entertainment afforded to the delegates who visited Cambridge and London for the meeting of the International Astronomical Union held last year.

To any of our readers who may be interested in houses or house building we would recommend a little book by Sir John Robertson, the Medical Officer of Health for Birmingham, entitled, *The House of Health* (Faber and Gwyer, Ltd., London, 1925. Price 2*s.* 6*d.* net). Although written primarily as a guide to the construction of small artisan dwellings of the subsidy type, it is full of hints which would be useful to anyone building or choosing a house of a more important character. The treatment is thorough and complete, beginning with the selection of a site and ending with a discussion of internal fittings and decorations. The information supplied is very practical, and wherever possible is based upon the results obtained by the Building Research Committee.

The January number of the *Empire Forestry Journal* maintains its high standard of interest—even to the layman. An article on the Forests of Papua and New Guinea describes the results of the first forest survey of these little known Australian territories, while other articles deal with the Forests of Cyprus, Forest Development in Burma, and with Peat and its connection with afforestation. As usual, the reviews and notes form a valuable and interesting section of the journal.

ESSAYS

DVI-MANGANESE. THE ELEMENT OF ATOMIC NUMBER 75.

(J. G. F. Druce, M.Sc., F.I.C.)

When Mendělejev drew up his Periodic Classification of the chemical elements, he assumed the existence of certain elements which had not then been discovered. The soundness and utility of his scheme were soon proved by the identification of three of the missing bodies during the next decade. Scandium, germanium, and gallium possessed the physical and chemical properties which Mendělejev predicted for his eka-boron, eka-silicon, and eka-aluminium. He also predicted the discovery of eka-manganese (atomic number 43) and dvi-manganese (atomic number 75); but beyond stating that they should resemble manganese in their chemical properties, he does not appear to have predicted their other properties.

Since Mendělejev's time numerous investigators[1] have endeavoured to detect the two elements missing in the manganese group. In his book *The Chemical Elements* (Methuen), F. H. Loring devotes a chapter to the then (1923) missing elements. He pointed out that their absence or rarity may be accounted for by one or two types of a mathematical series based on atomic number differences. If these elements exist, Loring concluded that they would be present in minute quantities only.

From theoretical reasoning Noddack and Tacke[2] argued that platinum ores and also certain minerals, *e.g.* columbite, should contain eka- and dvi-manganese to the extent of 10^{-8} to 10^{-6} in platinum ores and 10^{-6} to 10^{-6} in columbite, respectively. From these sources they claim to have obtained a "residue" containing 0·5 per cent. eka- and 5 per cent. dvi-manganese, for which they suggest the names Masurium and Rhenium (after two German provinces). Spectroscopic evidence by Berg and Tacke[2] is given in support of this claim. Their work has been criticised by Dolejšek and Heyrovský,[3] who had detected an impurity (1 part in 20,000) in the purest manganese sulphate and potassium permanganate by means of the dropping mercury cathode. The objection to the work of Noddack and Tacke lies in the fact that their observed lines $L\beta_1 = 1{,}204{\cdot}8$ and $L\beta_2 = 1{,}216$, measured to 0·1 X unit, agree better with the $L\alpha_1 = 1{,}204{\cdot}7$ and $L\alpha_2 = 1{,}216{\cdot}0$ of thallium than with those calculated for dvi-manganese ($L\beta_1 = 1204{\cdot}1$ and $L\beta_2 = 1{,}216{\cdot}9$). It seems probable that the minerals which they used contained thallium. Also, two other lines given by Berg and Tacke, they admit, coincide with those of tungsten, which was present in their final product.

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[1] Bosanquet and Keeley, *Phil. Mag.*, 1924, 48, 145.

[2] Noddack and Tacke, *Naturwissenschaften*, 1925, 13, 571 (June 26); Berg and Tacke, *ibid.*, p. 571. Tacke, *Zeit. angew. Chem.*, Dec. 17, 1925.

[3] Dolejšek and Heyrovský, *Nature*, 1925, 116, 782 (Nov. 28), and *Bulletin international de l'Académie des Sciences de Bohême*, 1925.

The Czech workers have obtained a product containing about 1·5 per cent. of dvi-manganese according to their polarographic and spectroscopic evidence. The independent discovery of dvi-manganese in manganese compounds had been announced previously by Loring and the present writer.[1] Our investigations had been partly prompted by the appearance in 1924 of a paper by W. Smith,[2] in which it was stated that pure manganese chloride was not obtained from pyrolusite by the methods described in the textbooks and works of reference. Smith's analysis of the pyrolusite he used shows 0·04 per cent. unaccounted for, and it occurred to us that a close similarity in properties had hitherto prevented the separation of manganese free from the higher members of the same group. In one respect at least, they behave differently. Noddack and Tacke had correctly predicted that the sulphide of dvi-manganese would not be precipitated by hydrogen sulphide (although they seem to have detected the new element in the insoluble sulphides from columbite; *vide* their experimental work). We, therefore, endeavoured to separate dvi-manganese from manganese by precipitating the latter in ammoniacal solution with hydrogen sulphide.

From the evaporated and ignited filtrate a residue was obtained which contained dvi-manganese. Its behaviour, polarographically and spectroscopically, was investigated in conjunction with the Czech workers in the laboratories of the Charles University, Prague. It was found to have a dvi-manganese content similar to their original product isolated electrolytically.[3]

Various methods have been tried with the view of increasing the purity of the product and of removing the rest of the manganese and trace of iron which were present in the crude dvi-manganese oxide. None have so far proved entirely satisfactory and others are still being tried. One of the chlorides of dvi-manganese is very readily volatilised, and this seems the most promising chemical method for effecting the isolation of pure compounds of the element of atomic number 75.

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[1] Druce, *Chem. News*, 1925, **131**, 273 (Oct. 30); Loring and Druce, *ibid.*, p. 337.

[2] W. Smith, *ibid.*, 1924, **128**, 1.

[3] Dolejšek, Druce, and Heyrovský, *Nature*, 1926, **117**, 159 (Jan. 30).

S. T. COLERIDGE AS A PHILOSOPHICAL BIOLOGIST

(Joseph Needham, M.A.)

It is probable that very few biologists are aware that the widespread genius of Coleridge extended even to their own sphere of being. Most of us are accustomed to think of him as the author of the elemental weirdness of *The Ancient Mariner*; a smaller number will be reminded of the illuminate hours they spent in the company of his *Biographia Literaria*. Fewer still will probably be acquainted with his notes on Æschylus and Dante; with his appreciation of Sir Thomas Browne or with the rest of his smaller writings, such as that delightful one on Fuller. It might almost be true to say that none will think of a rare piece of his work, *The Theory of Life* or the "Idea," or the "Physiology" of life—its title was never anything but amorphous—for indeed, though it created some little stir at the time, it has dwelt in total darkness since.

Curious it is to note a straw which goes whistling down the wind of specialisation. Had Coleridge lived a couple of centuries earlier than he did he might have been assured of immortality for his speculations in biology as well as in literature. But it seems to be a law of the times' procession that a reputation becomes a more and more restricted thing. A Francis Bacon could speak authoritatively of Fiery Meteors and almost in the same breath of Logic; no one could, as it were, quite lay a finger on what was his real subject. All Nature, and therefore all man, was his province; nothing was uninteresting to him, all things in heaven and earth were stamped for all eternity with the impress of his mind. Not so by 1800; already it has come about that a reputation in literature is just that and nothing more; excursions into science or the arts on the part of such a one may not pass unregarded, but will certainly be allowed no long persistence. Doubtless this tendency will almost wholly be due to the immense growth of the boundaries of human wits and knowledges, bringing it about that he who excels in science cannot expect to do so in the humanities. Yet will there not also be a habit of mind abroad which will reject almost from a priori grounds works on a subject by men whose reputations have been won in another? The crowd will more and more stop up their ears when poets speak to them of science, as does Coleridge here, and so, as if in an autocatalytic reaction, the entire process more speedily hastens on to its completion in a universe of hermetical cells.

Yet in this case, at any rate, it will not be uninstructive to resurrect for a moment from the tomb his little essay on Life, its nature and its meaning, for in it, among a deal of changing temporal stuff, there are some good sayings and some characteristic views, even in their unavoided pitfalls presenting strange analogies with things that are happening at the present day. Coleridge wrote *The Theory of Life* in all probability in the year 1831, but this is only known from internal evidence, since it was not published till long after his death, in 1848. The editor of it was one Seth Watson, M.D., of St. John's College, in Oxford, and there are passages in it obviously not Coleridge's, which must have been inserted probably to round off its naked lack of finish, by James Gillman, Coleridge's friend and literary executor at Highgate. These passages can be distinguished with fair ease, as the style is so different; for example, the Introduction begins with a great flourish of rusty trumpets as follows: "When we stand before the bust of John Hunter, or as we enter the magnificent museum furnished by his labours, and pass slowly, with meditative observation, through this august temple, which the genius of one great man has raised and dedicated to the wisdom of the Creator. . . ." Overleaf, however, we pass by an abrupt transition to Coleridge's best snappy dialectic style: "I perfectly agree with a later writer that loose and indefinite expressions are the bane of all science and have been remarkably injurious in the different departments of physiology." It is easy to tell, from considerations such as these, what is truly Coleridge's, and the result is practically everything.

The date assigned to the essay rests upon a reference which Coleridge makes in the Introduction to the work of the celebrated Dr. Abernethy, who died late in 1831, and from which the conclusion follows that it must have been written early in that year. Before we proceed to describe what it was that Coleridge said about Biology, it will be of importance to discuss the position of affairs in the philosophy of biology at the time it was written. The usage of the phrase "philosophy of biology" has been criticised lately on the ground that philosophy, as Plato said, means seeing things all as one, seeing things together, and that if philosophical speculations are confined to biological facts, then they ought not to be called philosophical. But I shall continue to use the expression, for it seems to me that it covers very well all that rather undefined realm of theoretical biology in which one may discuss the nature of evolution, the ability of physics and chemistry to offer full descriptions of animal processes and animal behaviour, the psycho-physical relationship, and the origin of life. It seems to me merely doctrinaire to restrict the use of the term "philosophy" to metaphysics. I can always take as my precedents Lamarck's *Philosophy of Zoology* and Cannizaros' *Philosophy of Chemistry*.

In 1831, then, what was happening in biology? Huxley, Mendel, Darwin, Pasteur, and Hoope-Seyler were still boys, as also were the elder Waller, Bowman, Sharpey, and Schleiden. The immense revolution which the cell-theory brought about in physiological thought had not yet been inaugurated. Theodor Schwann was in the very year in question still engaged with his experiments on developing eggs in which he finally disposed of the opinion that they could develop in irrespirable gases. Not until six years later did he publish his *Mikroscopische Untersuchungen* on the cellular nature of living stuff. Far away in Esthonia, Karl v. Baer was busy at the University of Dorpat with his immortal embryological researches; the first volume of his great work was already out, the second was not to come for many years. Purkinje and the Webers were in middle life, and one of the most important physiological events of the time was to occur five years later when Marshall Hall published the results of his work on reflex action. Indeed, the decade, as a whole, was a time of exceeding importance for biology in general. In morphology it was the dawn of emancipation from the Naturphilosophie school, which had so long dominated that branch of science with its fixed cut-and-dried plans of relationships, its perpetual search for facts to fit preconceived and very speculative theories. The star of transcendental biology which had been placed in the intellectual heavens by Goethe and Kielmeyer was setting, though slowly; Oken's Isis was gradually veiling herself for ever. In biochemistry profoundly important events were taking place. In 1828 Wöhler effected the synthesis of urea from purely inorganic substances in the laboratory, a research the influence of which upon the history of vitalism has been so frequently pointed out. Liebig was working at Giessen, and in 1829 had investigated the nature of hippuric acid, the first protective synthesis thus being brought to light. Perhaps even more important was the pronouncement of the physiologist Majendie, who in 1836 pointed out that living matter was invariably associated with the presence of the chemical classes, fats, carbohydrates, and proteins, these three being always present together. Then in the very year that Coleridge wrote down his ideas on the nature of life, the first enzyme was isolated, for Leuchs in that year discovered the Ptyalin in the saliva, and two years later Kirchoff found a similar ferment in seeds. In 1834 Rothamsted Experimental Station was founded—fertile date—and 1836 was remarkable because of the simultaneous and independent discovery of the yeast-cell as the active element in fermentation by Schwann, Kützing, and Cagniard de Latour. Another great man who was alive and active in 1831 was Thomas Graham, and thence one is reminded that a very significant date of this period was 1827, in which year Robert Brown discovered the movement of small particles which bears his name, thus with the former worker laying the foundation-stones of that colloid chemistry which has had so deep an influence on all biology. It helps us to gauge the atmosphere of the time when we find that Brown appended to his paper on the dancing of gamboge grains and coal granules a list of the country gentlemen to whom he had shown the experiment, and who could vouch for its truth. It was indeed a final vestige of that healthier time when scientific books were written not for any specialised "scientific public," but for anyone in all the realm who cared to read them; when discussions of learned men were carried on in the market-place, rather than the retired and solitary lecture-room. It was an echo; it was almost the last. Finally, since, as we shall see, speculations about the newly discovered force of electricity played so large a part in Coleridge's ideas, it is of interest to recall that Michael Faraday was at the time in full swing of research at the Royal Institution, Sir Humphrey being then just lately dead, while forty years before Benjamin Franklin also had mounted to that place whence in his lifetime he had stolen fire. The electric current was in everyone's thoughts; what could its nature be, and what its powers?

It would seem that Coleridge was quite ignorant of much of the sort of work which we have touched upon, and in many ways his treatment of the problem of life sounds in our ears much as do Bernard Shaw's discussions of the Life-Force. Considerable thought and great acuity are united to a vagueness about the relevant facts available at the time.

It is likely that Coleridge's mind had been occupied with the problem of the essential nature of living stuff for many years before 1831, for there were few problems which did not occupy it at one time or another. He had certainly been much concerned with that Platonic antithesis between the everlasting stream of changing things, the river of external facts encompassing the thinker on every side and the contrast between this and whatever unchanging absolutes there might be; so that animal bodies, as among the most changeable of things, may well have focussed his mind's activity. The individual flux; the unchangingness of the type (if indeed that was unchanging) may well have fascinated him. If this was the case, then the match which lit up the train of questioning in him may very well have been the famous statement of F. X. Bichat—"Savant anatomiste, d'ailleurs"—that "La Vie est l'ensemble des Fonctions qui résistent à la Mort." For he begins his essay by a biting criticism of this definition of life or any similar definition. "By a comprisal," he says, "of the *petitio principii* with the *argumentum in circulo*—in plain English by an easy logic, which begins by begging the question, and then, moving in a circle, comes round to the point where it began—each of the two divisions has been made to define the other by a mere reassertion of their assumed contrariety." He is clearly very dissatisfied with the definitions which scientific men had put forward, and he goes on to criticise some others. He will not allow that it is a sufficient definition of life to say that respiration, for example, is its essence. All animals, he says, that have lungs, breathe, but it would be a childish oversight to deduce the converse, namely, that all animals that breathe have lungs. Similarly, he argues, everything that breathes is an animal, but why should the converse necessarily be true? In other words, the flaw at the bottom of such definitions he conceives to be the assumption of causation from mere co-existence—a flaw which, as a matter of fact, other philosophers have felt to lie at the basis of any discussion of causation. Finally, he decides that the most satisfactory type of definition is that which simply states that living things differ from dead things in that they resist "to a certain extent whatever is incompatible with the laws that constitute their particular state for the time being." Coleridge, who had been the friend of many physicians, must have been well acquainted with the *Vis Medicatrix Naturæ*, and that must have entered into his thoughts when he wrote that this last type of definition was "far superior to the two former." He said indeed that it was still very unsatisfactory, and he might have used a stronger adjective if Le Chatêlier had been born.

Next he goes on to discuss the mechanistic view of life, or rather the iatromathematical foreshadowing of it. It is characteristic of human thought, he says, "to wish to look at all things from the one point of view which chances to be of predominant attraction." Sir Thomas Browne, who saw quincunxes in earth and under the earth, might have served for an exquisite illustration, but with rather less justice he takes Gilbert of Colchester, who, he says, wished to explain all terrestrial and celestial phenomena by the aid of magnetic influences. In like manner, the iatromathematicians have, as we should say, "run the mechanical explanation to death." "Should the reader," he says, "chance to put his hand on the *Principles of Philosophy* by La Forge, an immediate pupil of Descartes, he may see the phenomena of sleep solved in a copper-plate engraving with all the figures into which the globules of the blood shaped themselves, and the results demonstrated by mathematical calculations. In short, from the time of Kepler to that of Newton, and from Newton to Hartley, not only all things in external Nature, but the subtlest mysteries of life and organisation, and even of the intellect and moral being, were conjured within the magic circle of mathematical formulæ." Coleridge is no mechanist; he cannot see that mathematics and chemistry can be of any use where living matter is concerned. "How," he asks, "could men of sound judgments and strong minds have attempted to penetrate by the clue of chemical experiments the secret recesses, the sacred adyta of organic life, without being aware that chemistry must needs be at its extreme limits when it has approached the threshold of a higher power?"

Having thus made clear his absolute objection to all theories of life which claim to reduce it to a mathematical basis, Coleridge goes on to the exposition of his own, and begins by guarding himself against various objections. He denies that his own view of life can be called "occult" or vitalistic, but all he says against such a charge is "that he retorts it on those who can satisfy themselves that life is the peculiar power by which death is resisted." This is certainly weak, and, as will be seen, his own view of life is very largely "occult." But the line between "occult" and naturalistic explanations was not then very clearly drawn—"I must also reject fluids and ethers of all kinds, magnetical, electrical, and universal, to whatever quintessential thinness they may be treble distilled, and as it were supersubstantiated."

His first conception of life is that it is the principle of Individuation. "The most comprehensive formula to which life is reducible, would be that of the internal copula of bodies," he says, "or (if we may venture to borrow a phrase from the Platonic school) the POWER which discloses itself from within as a principle of UNITY in the MANY. But at the same time I will borrow a scholastic term and define life absolutely as the principle of UNITY in MULTEITY as far as the former is produced *ab intra*; but eminently, I define life as the principle of Individuation, or power that unites a given all into a whole that is presupposed by all its parts. The link that combines the two and acts through both will, of course, be defined by the Tendency to Individuation. Thus, from its utmost latency, in which life is one with the elementary powers of mechanism, to its highest manifestation there is an ascending series of graduated intermediate classes, and of analogous gradations in each class. The very fact that living matter possesses physical properties would, to a reflecting mind, demonstrate that, in the truth of things, they are homogeneous, and that both the classes are but degrees and dignities of one and the same tendency."

In many respects this paragraph is interesting. In the first place, the principle of unity acting in multeity must be considered as of doubtful value when applied to distinguish life from non-life. For every mountain and hill that Coleridge saw when he walked among the Lakes with his friend Wordsworth was different from its fellows; no two summits ever were the same, although in their formation physical causes might be conceded to have been supreme. If he meant by the principle of unity that regulative force of which he spoke earlier, so that, as it were, every living organism had a definite restricted individual home in time and space, in its external and internal environment, and that to this position it would always try to return, then the Tendency of Individuation is but another name for that nostalgia of organisms which Sir William Bayliss so well criticised on the basis of Le Chatêlier. Secondly, Coleridge's mention of grades and ascending steps is interesting, for it shows he was acquainted with the speculations of the German school of Naturphilosophie in biology. Again, when he speaks of different degrees and dignities of the same tendency do we not think at once of the conception of Emergence, and feel that in a certain sense he has anticipated it? For him, as for Lloyd Morgan, irruptions of creative energy, of the principle of Unity, if you like, occur at various levels in nature, the highest of which are life and mind.

Later on he expands this theme. He says, "I would take as the instance of the first step, the metals, those namely that are capable of permanent reduction. . . . Rising in the ascent, I should take, as illustrative of the second step, the various forms of crystals. . . . The third step is presented to us in those vast formations the tracing of which generically would form the science of geology, or its history in the strict sense of the word, even as their description and diagnostics constitute its preliminaries." From geological formations he proceeds to plants, from plants to insects, from insects to other animals, and so to man. The tendency to individuation rises in intensity throughout the series, which, were it expressed in terminology more informed by our wider knowledge, would correspond in a striking manner with the emergent evolution of the present day. It is evident that life, for Coleridge, does not mean anything like what it does in its usual acceptance:

There is a latent life, he would maintain, in all the inorganic, but it is of a low intensity, the inorganic world is asleep, adream, but yet not dead. This is indeed the philosophy of a poet, the Day-view, as Fechner called it. It is a universal panpsychism. The biological mechanist may well find such a view philosophically valuable, but from a methodological point of view it would be absolutely fatal to try to work it in, as it were, into the scientific method. That is the point which Coleridge never saw. Like the entelechy of Driesch, the nostalgia of Haldane, and the hormic urges of Russell, the sleeping souls in inorganic matter, the waking souls in living organisms, rise and try to attract the attention of the experimentalist as he goes about his business in the laboratory. That they will never do, for he wears magic spectacles, magic optic glasses, so fashioned as to render them altogether invisible. Wail as they will, he will never hear them; they may dance up and down sirenlike, he will never see them. Only when he lays aside the scientific method, then they may profitably converse with him; then only may he be able to consider without amusement " the dignity of the soul that sleeps within a mass of incandescent vapour."

Having established, then, to his own satisfaction that life consists in the fullest operation of unity in multeity, he goes on to try to formulate the most general law of its action. This he considers to be " Polarity." From this point the essay steadily declines in value and becomes very reminiscent indeed of the immortal quincunx. It is clear that Coleridge had been much influenced by the researches that had been going on in electricity and magnetism, much more so, in fact, than by those which the biologists had been conducting. The connection of Coleridge with the Royal Institution is the obvious cause of this; he lectured there on the work of Shakespeare, Milton, Dante, and other humanistic subjects.

Electrochemistry, rather than any other branch of science, was the one in which Coleridge was most at home, and thence he drew the idea of polarity which he erected into a general law of the most fundamental kind. It is as if Bernard Shaw, in writing a work on the Life-Force, were, by some accidental connection with the Cavendish Laboratory, to seek to show that the most general biological law was closely connected with the phenomenon of isotopes.

" We revert again," he says, " to potentiated length in the power of magnetism, to surface in the power of electricity, and to the synthesis of both, or potentiated depth, in constructive, that is, chemical affinity. But while these two factors are as poles to each other, each factor has likewise its own poles, and thus in the simple cross we have presented to us the universal quadruplicity, or four elemental forms of power in the endless proportions and modifications of which the innumerable offspring of all-bearing Nature consist. Wisely docile to the suggestions of Nature herself, the ancients significantly expressed these forces under the names of Earth, Water, Air, and Fire . . . and already our more philosophical naturalists (Ritter, for instance) have begun to generalise the four great elements of chemical nomenclature, carbon, azote, oxygen and hydrogen, the two former as the positive and negative pole of the magnetic axis, or as the power of fixity and mobility, and the two latter as the opposite poles or plus and minus states of cosmical electricity, as the powers of contraction and dilatation, or comburence and combustibility."

Assuredly this is a great fall from the undoubtedly profound discussion which occupied the first part of Coleridge's little book. In certain sentences now we might be listening to some Rosicrucian exponent of mysteries. Running through it all, as it is so interesting to observe, there is the terminology of the electrochemical school of the Royal Institution. The Ritter to whom he refers was a German physiologist who had died in 1810 and had worked much on galvanism, electrochemistry and physiological electricity. His many papers can be found to-day in forgotten journals such as *Crell's Annalen*.

Perhaps there is some parallel between electrical experiments at that period and psychological ones at the present day. Electricity was on everyone's lips; then and for the next twenty years; one may indeed recall the Sapphics of O. W. Holmes:

> Drops of deliquescence glistened on his forehead,
> Whitened round his feet the dust of efflorescence,
> Till one Monday morning, when the flow suspended,
> There was no De Sauty.
>
> Nothing but a cloud of elements organic,
> C, O, H, N, Ferrum, Chlor. Flu. Sil. Potassa.
> Calc. Sod. Phosph. Mag. Sulphur, Mang. (?) Alumin. (?) Cuprum (?)
> Such as man is made of.

So Coleridge concludes his discussion of polarity as the deepest law of organic life and passes on to refute the objections which a certain Mr. Lawrence had brought against his views in a lecture. This was probably Sir W. Lawrence, who died in 1867, Abernethy's assistant, and in 1831 Surgeon at St. Bartholomew's Hospital. Lawrence had said that electricity had nothing to do with life, that it illustrated life no more than life illustrated it. "We should be pleased to learn," he had said, "whether the human body is more like a load-stone, a voltaic pile, or an electrical machine; whether the organs are to be regarded as Leyden jars, magnetic needles, or batteries." Coleridge, who had been wrong in maintaining that life was all electricity, has now to combat the even more erroneous thesis that living matter has no electrical properties. This he does without difficulty, and finally proceeds to survey the whole field of life in order to show the universal presence of the law of polarity and the tendency to individuation.

It is here that he is at his worst. Hydrogen as the elementary power of dilation, the evaporable diamond, simulacra vitæ of copper ores, corals, conchylia, mollusca, tubipora, all are brought together and arranged in a scale the lowest point of which is the substance of the philosophers and the highest man. It would not be worth while to examine this part of the essay in detail; Coleridge, for instance, maintains that the insect world is the exponent of irritability, as the vegetable is of reproduction; in the best transcendental style. It is interesting to recall here that he had travelled widely in Germany. At the very end of his essay he recapitulates all that he has said, and in the last sentence achieves a certain depth. "Thus," he says, "Life itself is not a thing—a self-subsistent hypostasis—but an act and a process, which, pitiable as the prejudice will appear to the 'forts esprits' is a great deal more than either my reason would authorise or my conscience allow me to assert—concerning the Soul, as the principle both of Reason and Conscience." It is a good ending to an essay on Life, this definite, if obscurely worded, renouncement of that *petitio principii* inherent in all attempts to account finally for consciousness on physico-chemical grounds.

Looking back, then, it is seen that apart from the numerous points of interest for the historian of biology which arise out of Coleridge's essay, there are one or two matters in which he is clearly in touch with modern thought. His anticipation of the idea of Emergent evolution, or a crude form of it, and his biological Platonism are examples. But what is clearest is that, like so many of the modern authors on this subject, he failed to realise the metrical and quantitative nature of scientific method. The tendency to individuation, whether or not it has philosophical value, regarded scientifically, can only be considered as a doubtful short cut to a knowledge of life; it cannot be brought under the dominion of the statistical calculation, the pointer-reading, the clock and the scale. Therefore, whatever else it may be, it is no scientific theory of life. Coleridge was a better philosopher than a scientist, and that by a long way.

When he was young, Socrates resorted to Anaxagoras because he had heard that Anaxagoras taught that it was

Reason which arranged and caused all things. When he found that his explanations were all of secondary and mechanical causes, and that he said little about the eternal essence of Reason, Socrates grew tired and left him. So might any young man tire of the laboriousness, the analytical method, the self-restrictedness of natural science, and yearn for the more expansive limitless realms of metaphysical speculation. He learnt, indeed, in the end that neither path is a broad and royal one, but yet could never much sympathise with the mechanistic mind of the Anaxagorides, as we might call them. "It was as if," he says at the last, "someone had undertaken to prove that Socrates does everything through Reason, and had then gone on to show that it was because my body was constructed in a certain way, of certain bones and muscles, that Socrates is now sitting here in prison, voluntarily awaiting death." Yet Anaxagoras would be right in his way, in propounding such an explanation of Socrates' behaviour; the scientific method, he might have said, depends on our agreeing to assume that it is that kind of explanation we want. In science, we think AS IF it were Socrates' bones and muscles so arranged that were wholly responsible. We must imperatively have something which we can measure, which we can weigh; all outside that is a "Tale out of Boccace or Malizspini, an apparition, or a neat delusion wherein there is no more of happiness than the name." Such are the distortions of the scientific method; but have not other visions their distortions too? Has not poetry its licence, and, even in philosophy itself, are we sure that when we look at all things together our little eyes see true in that excess of light?

ESSAY-REVIEW

THE PROGRESS OF PREHISTORY. By β_1. Being a Review of **Human Origins. A Manual of Prehistory**, by GEORGE GRANT MACCURDY. [Pp. Vol. I, xxxviii + 440; Vol. II, xvi + 516.] (New York and London: Appleton & Co., 1924. Price 42*s*. net.)

THE labour that has been expended in the last hundred years in excavating prehistoric sites and publishing detailed accounts of the material found in them affords a striking testimony of the insatiable curiosity of man to know all that can be discovered concerning his own origin and history. The extent of the field that has already been covered is perhaps largely unappreciated in this country except by specialists. In the province of Liège, which has an area little greater than that of Surrey, over 400 Neolithic sites alone have been minutely examined, and one might walk for days round the Les Eyzies region in the Dordogne without ever being more than a few hundred yards from a known prehistoric settlement. With this wealth of material the task of surveying all that is known and summarising the evidence, as far as possible, in the form of a continuous narrative becomes a life's labour, and its achievement is, at present, the great need of prehistoric science. Within the past few years many authorities in several countries have published textbooks to some extent fulfilling that purpose, and these are indispensable to the student and of great interest to the curious lay reader. The principal ones known to English readers are those of MacAlister, Osborn, Sollas, Keith, Burkitt, Boule, Obermaier, and Klaatsch, the last three having been recently translated into English. One of the earliest manuals of the kind published in any language was the *Prehistoric Times* of Lord Avebury (1st edition 1865). While such books are of the utmost importance in furthering the progress of the science, it must be admitted that they have only an ephemeral value. The young branch of human inquiry with which they deal is making such rapid strides that, unless extensively revised, the textbooks are seriously out of date ten or even five years after they are written. *Human Origins* is a worthy addition to their number. Dr. C. G. MacCurdy is Professor of Anthropology at Yale, and as Director of the American School of Prehistoric Research in Europe he has had unique opportunities of obtaining that wide first-hand acquaintance with field-work which is so essential to the cultural prehistorian. Like some of its predecessors, this manual aims at covering the whole range of our acquaintance with man and his activities anterior to the historic era. The first volume is devoted to Palæolithic times, and the second to the Transitional, Neolithic, and Metal Ages. More space is given to the later periods than is usual in such works, and in another way it differs from the earlier compendiums. In compiling it the writer evidently sought to maintain an attitude of strict impartiality. His object was primarily to present the known facts and to deal only with those generalisations which are already well established, or, on important disputed points, to give the reader a fair idea of the diverse opinions that are held by the most competent authorities. The consistency with which that purpose has been carried out would seem to make the book unique. In many cases we are left wondering what the writer's own opinion on some debatable point may be. The treatment nevertheless gives a clear presentation of the present scope of our knowledge. In outline *Human Origins* follows the order usually adopted. The first chapter, giving a sketch of the development of prehistoric chronology, is followed by an account of the Ice Ages, and later chapters describe the successive Palæolithic epochs, Palæolithic art, and the remains of fossil man. The second volume gives summaries of the later periods, and a list of excavated sites, mentioning the cultural strata found in each, and giving select references. That catalogue takes up 116 pages, and it claims to be unique on account of its completeness. It will certainly prove of great value to the student. Other appendices give a "Repertory of Palæolithic Art," a short essay of the steps that have been taken to preserve prehistoric monuments in some European countries, and a classified list of such monuments in France. The indispensable illustrations and index are worthy of the work. Maps showing the geographical distribution in Europe of all the stations of the several Palæolithic periods discovered up to the time of writing, and the distributions of "Art Stations" are of peculiar interest. The absence of a separate account of the fauna of Quaternary times is a serious defect in such a manual. The reader is given little idea of the importance of animal remains in helping to establish the relative chronology of cultural stages.

For the greater part of the period for which we have any knowledge of man's activities, or even proof of his existence, the world was passing through a phase of its history differing from any previous one. The solution of the geological problems of the Ice Age makes possible the building up of the framework of prehistoric chronology. The prehistorian is only interested in those questions at present in so far as they concern the northern hemisphere and above all Europe. In the second chapter of *Human Origins* a concise account is given both of the theories of Penck and Brückner, establishing four periods of maximum glaciation for the Alpine area, and of those of Geikie. In main outline the two agree reasonably well. Dr. MacCurdy apparently accepts that classification, and would be willing to apply it in a general way to the greater part of Europe. Perhaps the reader might have been told more specifically that the views of Penck and Brückner are not accepted by all authorities, and that regions as close as Belgium and the south of England on the one hand and France on the other were, for at least a long period of Quaternary history, less alike climatically than they are to-day, so that the faunas for those two regions were, at times, appreciably different. The whole question of the synchronisation of valley terraces and raised beaches with one another and with the movements of the glaciers has yet to be worked out, and there is no uniformly accepted correlation of the geological and human cultural stages. A short summary is given of the most recent researches into the late Pleistocene history of "Fenno-Scandia," and it is evident some of the conditions found there are peculiar to that area. Such local differences are of vital importance to the prehistorian, and, at present, we know all too little about them.

An impartial account is given of the main evidence adduced in support of the theory that some flints found in tertiary deposits were humanly fashioned, or rather re-touched. Such claims are made for an ever-increasing number of specimens from England, France, and Belgium, and most prehistorians are now willing to concede the authenticity of some of them. Perhaps there will always be sceptics until worked flints are found in a tertiary deposit in indubitable association with fragments of the skeleton of a precursor of Quaternary man. Like many others, MacCurdy finds the most convincing proof of the genuineness of Eoliths in the well-known discoveries of Reid Moir in East Anglia.

The successive Palæolithic epochs are described in the first volume of *Human Origins*, and the method of presentation follows that commonly used. The general characteristics of the epoch, the environmental conditions, artifacts, and principal stations are dealt with in some detail, and for each there is a list of known stations and a map showing their distribution. Such a method of treatment is liable to give a distorted picture unless insistence is laid on the variations found between contemporary cultures in different regions. As our knowledge of Palæolithic times is increasing, it is becoming more and more evident that the unwritten history, like the written, of one area is often essentially different from that of other areas which may be geographically quite close. When considered in detail the regular sequences found for limited areas are seen to be largely localised so that it is unsafe to apply them to other areas less perfectly studied. To suggest that the generalisations which have been drawn from the records of the most intensively worked-up area in the world—the Dordogne region, which also appears to have been the capital of civilisation for a period of enormous length—can be applied to all Western Europe is now seen to be distinctly dangerous. The importance of a geographical as well as a stratigraphical treatment in summarising our knowledge of early cultures has been insisted on in Obermaier's recently translated *El Hombre Fósil.*[1] The conclusions drawn there relating to the origins and interrelations of cultures are certainly no more than tentative, and, as Dr. MacCurdy's aim was evidently to restrict himself to conclusions which have already been well established, such hypothesising would have been foreign to his scheme. But it would have been entirely consonant with it to insist more on the importance of the well-recognised differences found between the cultures of such neighbouring regions as Central France and Northern Spain. He tells us, for example, that six phases, or levels, have been noted in the Magdalenian epoch, and outlines the evolution of the javelin point and the harpoon, those two bone implements largely determining to which particular stage a cultural stratum may be assigned. But the omission to remark that such a sequence, which has been found, from the study of hundreds of specimens, to hold with wonderful consistency throughout the Dordogne region, may not be applicable to other localities is likely to give an entirely false impression. Obermaier states that the harpoons of Northern Spain form a homogeneous series peculiar to that district, and there, too, they play an important part in helping to determine the subdivisions of Magdalenian strata. Although numerous sites of the same age have been excavated in Belgium, only seven harpoons have as yet been found—four coming from a single station—and it is suggested that they were imported.[2] From a wider point of view, such facts, as the absence of a warm Mousterian phase in England and Belgium and the distinctiveness of the Caspian industry in Spain emphasise clearly the importance of the geographical factor. The same point is well illustrated by the excellent account of the beginnings of pictorial art given in *Human Origins*. It is shown by the distribution maps given there that the Altamira, the Pyrennees, and the Les Eyzies areas have revealed more Palæolithic art stations than all other parts of Europe, and all the finest examples come from those very restricted regions. Examples of later peoples living side by side for long periods of time at very different levels of culture are not lacking. The greater part of Europe was in a semi-barbaric state while the civilisations of the Mediterranean flourished and waned.

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[1] *Fossil Man in Spain.* Yale University Press, 1924. Translated for The Hispanic Society of America by Christine D. Matthew, and revised by Henry Fairfield Osborn.

[2] See Hamal Nandrin and Servais: La Grotte du Coléoptère. *Revue anthropologique,* 1925, nos. 4–6.

The chapter on fossil man gives a full list of the known remains and the views respecting them which the most competent authorities have held. It is prefaced by a short account of existing and fossil primates. The impartiality of the presentation is again its most salient character, and there is no discussion of the wider and much disputed questions of the genealogical history of man and his relationship to the anthropoids. The section dealing with the Piltdown controversy is particularly well done. "In the first phase, the lower jaw, though admittedly ape-like in character, was nevertheless regarded as having belonged to the same individual as the skull. Then came a period when in the minds of many the mandible was referred to a genus entirely different from that of the skull, namely, *Pan vetus*, a fossil chimpanzee. In the present or third phase it is asserted by the British group that important and hitherto overlooked features of the lower jaw are positively human, and that the teeth are not only human but fundamentally unlike those of the great apes." But there are still divergencies of expert opinion on the subject, and the reader who knows little of physical anthropology may well wonder whether the opinions of even the most eminent authorities on such matters are of much permanent value. That such questions should be discussed with keenness is proof enough of the virility of the young science, but it is equally evident that the chance discovery of even a few more fragments of early Palæolithic man will throw more light on the question of human origins than the further detailed study of those we already possess. Nature has perhaps never shown us more unexpected documents than in this chapter of her record. A femur of a modern type is found in association with a skull cap which takes us half-way back to an ape-like form ; modern teeth have their roots in a simian jaw, and an individual with a high brow is found to have no chin. The few human remains of pre-Mousterian date known to us are sufficient to show that the characters of modern man have not all been developed at the same rate. Dr. MacCurdy remarks that if the teeth of the Heidelberg jaw had been missing they would no doubt have been reconstructed along very different lines, and the same might be said of the Piltdown mandible if it too had not been found. He would concede little scientific value to the attempted reconstructions of incomplete skeletons of fossil man, and there are no reproductions in *Human Origins* of those busts and pictures of our Lower Palæolithic ancestors which adorn some textbooks.

The lack of apparent continuity in the evolution of man from an ape-like form is nowhere more in evidence than when Lower (Mousterian) and Upper Palæolithic remains are compared. Our knowledge of the apparently homogeneous type living in Europe towards the end of the earlier period is now based on the skeletal fragments of some thirty to forty individuals, and the majority of the characters of the type are seen to be intermediate between those of modern man and the existing anthropoid apes. A list is given of such pithecoid characters of Neanderthal man, but more emphasis might have been laid on the fact that some characters, and, in particular, such an imporant one as the prognathism of the jaws, do not distinguish *Homo neanderthalensis* from *Homo sapiens*. The majority of the Upper Palæolithic skeletal remains known to us are universally agreed to be of an entirely modern type, and ever since the distinctiveness of the Mousterian race was recognised anthropologists have been on the look-out for individuals showing a transitional stage between the two. But whether any have as yet been discovered is still a moot point, and it seems that Dr. MacCurdy was acting with less than his usual caution in stating, as he does in an earlier chapter (vol. I, p. 158), and in the list of remains of uncertain date, that some of the skeletons, or rather skulls, do represent intermediate types. The evidence of undated remains—such as those of Bréchamps, Marcilly-sur-Eure, Eguisheim, and Tilbury—and skulls lacking the facial bones are not of much value, and it is not generally supposed that either the Combe Capelle (Aurignacian) or the Chancelade (Magdalenian) skeletons are in any way intermediate in type between the Neanderthaloid and modern races. The almost complete male Aurignacian skull from Prědmost appears to be the only specimen for which a strong case could be made out, and it is only one of a series—no Neanderthaloid affinities being generally claimed for the other skulls—and it has itself not yet been fully described. It is quite reasonable to suppose that the existence of intermediate types has not yet been demonstrated.

In the second volume of *Human Origins* MacCurdy writes: "Various attempts have been made to establish a relative chronology for Neolithic times. Some seem to hold good for the countries in which they were developed, but when an attempt is made to adapt them to other regions, serious difficulties arise." The geographical rather than stratigraphical treatment which he adopts is naturally imposed. The lack of uniformity which he comments on emphasises again the uncertainty of the attempted correlation and synchronisation of the Palæolithic sequences established for different areas as for the earlier periods the material is far less ample. In the 300 pages devoted to the Transitional, Neolithic, and Metal Ages, it is hardly possible to give more than a bald summary of the principal results arrived at by workers in different countries. Though some writers may have attributed too much importance to Egyptian influences on European civilisation, there can be little doubt that too little notice of the civilisation of the Eastern Mediterranean has been taken here. It is not by any means clear why an account which, in the words of the wrapper, claims to tell " the whole story of prehistoric man " should have been practically confined to Western Europe for the later periods. The English reader would have welcomed some account of the prehistoric civilisations of America, but none is given in this volume.

One or two points of minor importance may be commented on. It is said in the preface that the first appearance of the word " prehistoric " in the title of a book was in 1862, when Sir Daniel Wilson published the first edition of his *Prehistoric Man.* But the *Prehistoric Annals of Scotland* by the same writer had appeared in 1851. The definitions of " brachycephalic " and " dolicocephalic " given in the glossary are " short-headed " and " long-headed," and they are those found all too frequently in books of a more popular nature. The markedly dolicocephalic Veddahs of Ceylon are " shorter-headed " than many European brachycephalic races, and the dolicocephalic Neanderthaloid skulls are as " broad-headed " as any brachycephalic types of modern man. The word " cleaver " is used as the equivalent of De Mortillet's *coup de poing.* In the translation of Obermaier's *El Hombre Fósil* " hand-axe " is used, and Sollas has invented the word " boucher " for the same tool. There is no special mention in the text of the attempted determinations of the absolute chronology of the Palæolithic periods, but estimates of age are given in years below some of the figured artifacts. An Upper Acheulian " cleaver," for example, is said to have been manufactured 125,000 to 100,000 years ago, and without further comment that certainly suggests to the uninitiated reader that its age could definitely be placed within those wide limits. Perhaps the limits themselves have a possible error of 50,000 years. The presentation of a diagram (as Vol. I, Table II, p. 27) showing the succession of cultural stages from Eolithic to Iron Age times with no indication of the probable relative duration of each, or mention of the fact that different stages occupied vastly different periods of time, is likely to be misleading also. The numerous photographs of Palæolithic skulls are reproduced from the original memoirs describing them, and hence it was not possible to present all the facial views with the same orientation. But it would have been possible to standardise the profile aspects, though it was not attempted. " Gonion " is defined incorrectly in the glossary to be a " Craniometric median point on the lower jaw below the chin " : that is probably the gnathion of Martin, the gonion being defined by all craniometricians to be a point on the angle of the lower jaw. But these are slight blemishes in a book which is a valuable and authoritative summary of our present acquaintance with man's prehistoric past.

REVIEWS

MATHEMATICS

Differential Equations. By H. B. Phillips, Ph.D. Second edition rewritten. [Pp. vi + 116.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, 1924. Price 6*s*. 6*d*. net.)

This is a useful little introduction to elementary types of ordinary differential equations, written from the practical point of view of the physicist or engineer. The object is to combine the formal exercise of solving differential equations with the actual setting up of the equation from a physical problem, and so the book contains a large and valuable collection of examples drawn from a variety of subjects, chemistry, electron theory, hydrodynamics, biology. The most striking omission is of any mention of Clairaut's equation; this is not to avoid the thorny topic of singular solutions, which are referred to in connection with first order equations of higher than the first degree in the differential coefficient. Also, the methods suggested for determining a particular integral of a linear equation with constant coefficients are rather vague and leave one with the impression that there is a lot of guess-work about the matter. There is, naturally, very little theory—" it is shown in calculus " is a frequent phrase—and one doesn't look for it in a book of this type, but the talk on page 28 about expanding the diagram " until the distance FF′ is a million miles, while PQ is only one inch " is surely a little crude, even for an engineer. There is a surprisingly full index, with such entries as " growth, of yeast " and " ventilation."

F. P. W.

A Practical Treatise on Fourier's Theorem and Harmonic Analysis for Physicists and Engineers. By Albert Eagle. [Pp. xiv + 178.] (London: Longmans, Green & Co., 1925. Price 9*s*. net.)

The practical chapters of this book are to be recommended as giving a succinct account of the methods of analysing any given curve or set of observations into its harmonic constituents, if it be harmonic, and of detecting any periodic component, if it be not. The author gives the name " artificial function " in a given interval to a function defined in each of a finite set of sub-intervals into which the whole interval is divided as a finite, continuous function with continuous differential coefficients of any order. Such an " artificial function " $f(x)$, defined in the range 0 to 2π, has, as is well known, a Fourier expansion, $\frac{1}{2}a_0 + \Sigma a_n \cos nx + \Sigma b_n \sin nx$, converging at any point in the range to $f(x)$ or $\frac{1}{2}\{f(x+0)+f(x-0)\}$ according as x is not or is a point of discontinuity. The Fourier coefficients a_n, b_n are given by the usual integrals or in terms of the discontinuities of $f(x)$ and its differential coefficients (p. 59). Numerous examples of such expansions are worked out in the text and others are given as examples. The author then proceeds to the practical question of the harmonic analysis of a given periodic curve. After somewhat severe strictures upon mechanical Harmonic Analysers he describes two methods of procedure, the usual one of obtaining a Fourier series with the least number of lowest harmonics which will give a function agreeing with the curve for a certain finite set of values of x, and another, which he claims as new, in which the given points are joined by straight lines or by arcs of parabolas of the second or third degree and the Fourier series of this built-up curve is obtained from its discontinuities. The method is valuable when a graph is given " if we take ordinates at such a distance apart that it is obvious to the eye that the form of the curve between two ordinates is very approximately parabolic." This chapter is well worth study and application. A later chapter deals with the search for periodicities in observed data not periodic, such as those of the meteorologist, first by the application of Fourier's integral theorem and the plotting of the " energy " curve, and secondly by the simpler method depending on the remark that if we add the values of a function for equidistant intervals all harmonics save those for which the interval is a period tend to cancel out. This latter method is given in Whittaker and Robinson's *Calculus of Observations.*

So much for the practical part of the book, which is competent enough. But, unfortunately, the author has seen fit to add some theory because " most students of physics and engineering do show a considerable interest in the proofs of the various mathematical methods and operations taught them." Candidly, one's advice to such students is *not* to read the chapters in question. The author makes the subject so mysterious and difficult. He says (p. 176): " for ourselves we can hardly make out how it could have escaped detection in Fourier's day that the series $\frac{\sin t}{1} + \frac{\sin 2t}{2} + \ldots$ when $t = 0$, can have any value that $\int_0^X \frac{\sin x}{x}\,dx$ can take." Surely there is no way of avoiding the conclusion that when $t = 0$ the value of the series *is zero*, and it will only confuse the student if he is told otherwise. It is a matter of non-uniform convergence, of course, a term which Mr. Eagle carefully avoids, if indeed he has heard of it; but, in any event, he might have found room in his " brief historical sketch " (Chap. X) for a mention of George Gabriel Stokes, whose name is associated with the discovery of the phenomena in question. Stokes was essentially an applied mathematician and not one of those whom Mr. Eagle somewhat contemptuously describes as inventing curious functions " for the sake of causing trouble " (p. 139). The elementary theory of Fourier series can be put accurately in an easily intelligible way, but Mr. Eagle does not come anywhere near doing it. And if it is true that the engineer has no clear ideas about " the so-called, and very badly called, ' imaginary quantities,' " the introductory chapter of this book is about the worst possible way of presenting them to him. As a matter of typology, too, we must protest against the use of the symbol for " varies as " in place of the symbol for " infinity."

F. P. W.

Traité du Calcul des Probabilités et de ses Applications. Tome 1. Fasc. 1: **Principes et Formules Classiques du Calcul des Probabilités.** Tome II. Fasc. 3: (**Mécanique statistique classique**). Par Émile Borel. [Pp. ix + 160; iii + 148.] (Paris: Gauthier-Villars et Cie., 1925. Price 18 fr. each part.)

Calcul des Probabilités. Par Paul Lévy. [Pp. viii + 350.] (Paris: Gauthier-Villars et Cie., 1925. Price 40 fr.)

Laplace's *Théorie analytique des probabilités* was published in 1812; in the well-known *Essai philosophique* which forms the introduction, the author insisted on the importance of the theory in various departments of human activity. To-day this is almost a commonplace. The physicist uses the theory to explain the inner properties of matter, the biologist to investigate the laws of heredity; the actuary, the statistician, the astronomer, the soldier all require some knowledge of it for their work. In M. Borel's opinion the time has now come to put together in a treatise the essential results of the theory and its applications. He has therefore got together a band of collaborators and has planned what will undoubtedly be a tremendous work of great importance. There are to be four volumes, each consisting of four or five parts. One volume is to deal with the abstract theory, another with its applications to physics and mathematics, the third with applications to biology and actuarial problems, the last with various other applications, winding up with a philosophical discussion of the bearing of the whole by M. Borel himself.

The first part to appear was t. iii, fasc. 1, *Assurances sur la Vie : Calcul des primes*, by M. Galbrun, and now two further parts have been published, each consisting of a course of lectures by M. Borel, edited by a pupil. Both are extremely well written, and may be confidently recommended.

The first, on the classical formulæ of the theory, begins with the a priori definition of probability as a number, lying between 0 and 1, assigned to each "event" and satisfying two laws of combination, the principle of the addition of probabilities and the principle of compound probabilities. The three kinds of probabilities, discontinuous, continuous, and denumerable, are then explained. Discontinuous probabilities for a large number of trials lead to the fundamental law of Gauss, and the results are applied to problems of the second order and to the theory of correlation; continuous probabilities lead to some very pretty and difficult mathematics. The second section treats the functions of statistics, giving examples of continuous functions with derivatives everywhere discontinuous. This leads on to the "problem of moments," associated with the names of Stieltjes and Tchebychef, by which, given an arbitrary function $f(x)$, increasing in a finite, positive interval (a, b), from a knowledge of the first $2n$ moments we can construct a function "en escalier," of n steps, which gives an approximation to the initial function, tending to this as a limit when the number of steps increases indefinitely.

The lectures on statistical mechanics are also well worthy of attention. Beginning with the definition of elementary probability, the author goes on to kinetic theory and the Maxwell law, the most probable state and questions of specific heat, mean free path, diffusion and entropy. The classical theory is alone discussed; it forms the necessary basis for the modern developments of the discontinuous statistics of the quantum theory, which are left to a later part.

The main part of M. Lévy's book deals with the law of Gauss as the limit to which, in very general circumstances, any law of probability tends. The method consists in the use of the idea of "characteristic function." The author published several notes on the method in 1922–3 in the *Comptes Rendus*, and was surprised to learn by a letter from M. G. Pólya, whose knowledge of all branches of mathematics is astounding, that it had already been developed to some extent by Cauchy in 1853. No subsequent writer had, however, referred to it, and M. Lévy therefore judged that a systematic treatment would not be out of place. He further gives indications of a more recent method, due to M. Lindeberg, and has chapters on exceptional laws, and on applications of the theory to kinetic theory and to the theory of errors. It is all very much harder reading than M. Borel's book. He has added a preliminary part, philosophical rather than mathematical, which strikes one as rather vague and unsatisfactory, but the main part of the book is well worth detailed study.

F. P. W.

Cours de Mathématiques Générales. Par G. VERRIEST. 2e partie: Géométrie analytique à trois dimensions. Calcul intégral. [Pp. 388.] (Paris: Gauthier-Villars & Cie., 1925. Price 38 fr.)

THE first part of this work has already been noticed in SCIENCE PROGRESS (vol. xix, October, 1924, p. 332). The second is of a similar character and provides a good, readable introduction to solid geometry, the integral calculus, and differential equations for the natural science student, and in particular the physical chemist. The solid geometry is rather slight, the plane and the straight line, a little elementary differential geometry of curves and surfaces, and finally a short account of the ellipsoid, as arising in elasticity and crystallography. The calculus is fuller and roughly covers the ground of Part I of the Mathematical Tripos, with, in addition, a good deal of thermodynamics, a chapter on the potential and appendices on the method of least squares, empirical functions, and interpolation. The book is excellent for its purpose. F. P. W.

Tables and Charts for the use of Engineers and Others, giving Values of X^n. By A. D. BROWNE. (9 pages, un-numbered.) (Cambridge: W. Heffer & Sons, Ltd., 1925. Price 1*s.* 6*d.* net.)

THESE are intended to save time in numerical calculations of x^n for values of n between 0 and 2 when an accuracy of about 2 per cent. is sufficient. When x lies between 1 and 10 the values may be read direct from the charts; to extend the range to between 0·001 and 10,000 tables of values of 10^n, 100^n and $1{,}000^n$ are given on the opposite page, and a single division or multiplication on the slide-rule does the rest. Similarly, for values of n which exceed 2, a single multiplication on the slide-rule is required. In the last line but four of the instructions x is a misprint for n. F. P. W.

Mémorial des Sciences Mathématiques. Fasc. II. **Fonctions entières et fonctions méromorphes d'une variable.** Par G. VALIRON. Fasc. III. **Séries hypergéométriques de plusieurs variables.** Par P. APPELL. [Pp. 50, 59.] (Paris: Gauthier-Villars & Cie., 1925. Price 10 fr. each.)

THIS is a most excellent series of pamphlets, published under the patronage of the Paris *Académie des Sciences*, the Rome *Accademia dei Lincei*, and some ten other scientific societies of Europe. It aims at giving succinctly and without detailed proofs an account of the principal results which have been obtained, and the lines upon which progress is being made at the present time in a number of branches of mathematics, pure and applied. The authors are to be men who have themselves made contributions to the subject. Each part is to contain an ample bibliography at the end, to which references are made throughout. If the *Mémorial* can keep up the standard set by these two, its usefulness is assured. M. Valiron deals with the theory which arose from the attempts to prove, without appealing to the elliptic modular function, Picard's theorem that a uniform function takes in the neighbourhood of an isolated essential singularity every value save two at most. This was done by Borel, for integral functions, by considering the mode of growth of the function $M(r)$, the maximum modulus of the function for $\|z\| = r$. He was then led to relations between this function and the density of zeros of $f(z) = x$, and it is work on these lines which is here described. M. Appell gives an account of the various generalisations of hypergeometric functions to several variables, from the point of view of Gauss—due to Appell himself and carried further by P. Humbert and S.

Kampé de Fériet—and from the point of view of differential equations—work begun by Picard and Goursat. He also deals with Hermite's algebraical extensions of the Legendre polynomials, explaining how they may be connected with spherical harmonics in hyperspace, a work equally initiated by Appell.

The general editor, M. H. Villat, has published a formidable list of parts in the press or in preparation, many of which any mathematician will look forward to with the greatest eagerness.

F. P. W.

ASTRONOMY

Practical Astronomy. A Textbook for Engineering Schools and a Manual of Field Methods. By PROF. G. L. HOSMER. Third Edition. [Pp. xii + 270, with 80 figures.] (New York: John Wiley & Sons; London: Chapman and Hall, 1925. Price 13*s*. 6*d*. net.)

PROF. HOSMER's book is now sufficiently well known to need little in the way of recommendation, and the fact that it has reached its third edition is evidence of the demand which still exists for an elementary practical astronomy. For the benefit of those who are not acquainted with the book, it may be remarked that the author has written it specially for civil engineers, with the intention of producing a book " intermediate between the textbook written for the student of Astronomy or Geodesy and the short chapter generally given in textbooks on Surveying." It is, therefore, confined to elementary spherical astronomy (with special attention given to practical calculation), together with the use of the simpler field instruments. The treatment is mostly the conventional one, and the usual chapters are given on the celestial sphere, time, instruments, and corrections, as well as on practical observations, in which special stress is laid on azimuth determinations. There is also a chapter on the American Ephemeris (including a section on interpolation) which may be adapted by English readers to apply almost equally well to the Nautical Almanac, while other chapters are given on the constellations and on Nautical Astronomy. It is evident in reading the book that Prof. Hosmer has first-hand practical knowledge of field astronomy, while possessing additional advantages in the power of appreciating beginners' difficulties and expounding his subject with clearness and simplicity. It is essentially a practical book, giving numerous tables, practical hints, and illustrative examples fully worked out, so that those for whom it is written will find it both clear and comprehensive for their purpose, though the article on the sextant might perhaps have been rather more exhaustive. For the convenience of beginners the articles of a more advanced nature are printed in small type, and may be omitted, if desired, on a first reading. In the latest edition various alterations are introduced; some, of course, necessitated by the change of time, others (such as the change of notation, together with textual alterations and extensions) rendering the book more complete and up-to-date. Various new tables and an appendix on spherical trigonometry have been added. The general form of the book has been made handier by reducing the size of the pages, printing on thinner paper, and binding in limp covers, thus making it a genuine pocket book for the field engineer or surveyor.

Meteors. By PROF. C. P. OLIVIER. [Pp. xx + 276, with 23 plates.] (Baltimore: Williams & Wilkins Co., London: Baillière, Tindall & Cox, 1925. Price 30*s*. net.)

THE study of meteors is a branch of astronomy which has a very great attraction for many people, and especially for amateur astronomers, for two reasons. In the first place there is the appeal to the imagination in the spectacular display with which a night's vigil may be rewarded, together with the uncertainties surrounding any attempt at quantitative forecasts; and secondly, the observational aids necessary to the production of useful observations are within the reach of everyone. It is rather surprising, therefore, that the literature of the subject has been comparatively scanty, and restricted in the main to papers scattered amongst various scientific periodicals. There is a chapter on meteors in most popular astronomies, but until the publication of Prof. Olivier's book there has not been—at least for English readers—any satisfactory or comprehensive handbook of the subject. Prof. Olivier has, therefore, rendered a valuable service to meteoric astronomy in the production of his book, which gives a summary of the above-mentioned scattered papers as well as an exhaustive account of the present position both factual and theoretical, of this interesting branch of astronomy. It can scarcely be termed a popular work, since it is evidently intended only for the serious student of meteoric astronomy; but it may be read by anyone of average education who is sufficiently interested in the subject (with the exception, perhaps, of a few mathematical chapters which are conveniently segregated and may be omitted without loss of continuity). After introductory chapters on the history of meteors and methods of observing them, the author devotes five chapters to general accounts of the principal meteor swarms, including full accounts of the observations made at various returns of these showers, together with the facts and theories which may be based on the observations. A discussion on radiants (including the controversial topic of stationary radiants) follows in the next three chapters, after which individual meteors are given special attention. The mathematical chapters on the computation of real heights, orbits, perturbations, and allied questions, include a considerable amount of material translated direct from Schiaparelli's *Sternschnuppen*, and the publications of Lehman-Filhès. Controversial issues are not shirked by the author, though he is careful to distinguish between expressions of his own opinions and theories which receive in addition the general support of other observers. English readers may occasionally be irritated by Americanisms, both in style and spelling, and the number of accidental errors is rather greater than might be expected even in a first edition. The plates, also, though for the greater part excellent, seem in several instances to possess little or no apparent bearing on the text. These, however, are minor faults, some of which, it may be hoped, will be remedied in a future edition. The book is certainly unique, and while it may be greatly appreciated by anyone with general scientific interests, it is scarcely an exaggeration to say, in the present state of the literature of the subject, that it will be indispensable to the student or observer in the realm of meteoric astronomy.

PHYSICS

Photo-Electricity. Monographs on Physics. By H. STANLEY ALLEN, M.A., D.Sc. [Pp. xi + 320, with 43 figures.] (London: Longmans, Green & Co., 1925. Price 18*s*. net.)

A SECOND edition of Professor Allen's book on photo-electricity has long been overdue, for, since the appearance of the first edition in 1913, a large amount of experimental work has been done—although it must be realised that much of this work refers to the effects produced by X-rays and γ-rays, and Professor Allen confines his attention to electrons liberated by ordinary and ultra-violet light. In this edition the space devoted to some of the earlier work, which is now chiefly of historical importance only, has been reduced, and suitable treatment has been accorded to more recent work, such as that of Millikan. Very complete references are everywhere given, and the book contains a valuable bibliography of work done since 1913. There are one or two omissions which might be rectified in a future edition; a chapter on photo-chemical actions is scarcely complete without some reference to the work of Franck and his collaborators on the effects of collisions of the second kind, and further, Franck's suggestions on photo-sensitisation are worthy of inclusion. The work of Ewles on the connection between fluorescence and molecular change might also be mentioned in the chapter on fluorescence. However, the field is so large that some work must necessarily lose the attention it deserves, and Professor Allen is to be congratulated on his success in giving us such an up-to-date book of reference.

L. F. BATES.

Electrical Precipitation. Physics in Industry. Volume III. By SIR OLIVER LODGE, D.Sc., F.R.S. [Pp. 40, with 5 plates.] (London: Oxford University Press, 1925. Price 2*s.* 6*d.* net.)

THE Institute of Physics has done very useful work in placing before the general public the important applications of physics to industry, and we therefore welcome the appearance of this book, in which is reproduced, in a convenient form, the seventh public lecture delivered under the auspices of the Institute. Sir Oliver Lodge always has something interesting to say, and his account of electrical precipitation will appeal to all physicists. The lecture deals with natural and with artificial precipitation and its practical application in the recovery of dust from furnace gases, etc.; detailed information of examples of commercial precipitation are given in an appendix, drafted by Lionel Lodge.

L. F. B.

"**Modern Magnetics.**" By FELIX AUERBACH, Professor of Physics in the University of Jena. Translated by H. C. BOOTH, A.R.C.Sc. [Pp. vii + 396, with 167 diagrams.] (London: Methuen & Co., Ltd., 1925. Price 15*s.* net.)

THE German edition of this book was published in the early part of 1921 under the title *Moderne Magnetik.* It was, in fact, an abridged edition of a much more comprehensive article on magnetism which formed part of Graetz's *Handbuch der Elektrizität und des Magnetismus. Moderne Magnetik* was primarily designed to meet the requirements of teachers and technologists, but it was also intended to appeal to the general reader. Now, the English translation appeared towards the end of 1925, and it is therefore natural to inquire what steps have been taken to render the English edition more completely up-to-date than its German forerunner. The answer to this inquiry is, that as far as we can see, no such steps have been taken. This is decidedly a pity, because we have great need of a first-class book on magnetism, and we cannot help feeling that a splendid opportunity of satisfying this need has been lost, and lost because of the lack of a little careful revision.

Prof. Auerbach's work contains much useful matter; there are excellent sections on the experimental facts of magneto-optics, the Hall effect and allied phenomena, electromagnets, magnetic measurements and the earth's magnetism. Unfortunately, owing to lack of revision, some sections are inadequately treated. Thus, the gyromagnetic effect is very poorly presented; for no work subsequent to 1916 is described, and readers are given a completely wrong impression of the present state of our knowledge of this branch of the subject. Again, whilst the book gives the impression that the Weiss magneton is a universal natural constant and the foundation-stone from which magnetic atoms are built up, we find no reference to the Bohr magneton, and, incidentally, no reference to Bohr's views on the magnetic properties of the elements. We look in vain for a satisfactory presentation of the quantum theory as applied to magnetic phenomena, and we find no mention of the experiments of Gerlach and Stern, although these experiments, whatever their importance or meaning, have found their way into English textbooks.

On page 18 there is an elementary mistake, and in the table of magnetic susceptibilities, on page 84, we find that glass is classified solely as a diamagnetic substance, with a mean value of κ equal to $0{\cdot}9 \times 10^{-6}$, a classification which is obviously incorrect when we remember the number of paramagnetic glasses in everyday use. A bibliography is given at the end of the book, but its value would be greatly increased if it were brought up-to-date. Surely, the recent measurements of the diamagnetic susceptibilities of gases by Hector and Wills and by Soné are worthy of note in a bibliography, even if lack of space forbids their inclusion in extenso in the book itself. Further, the omission of an author's index (or of the names of authors from the general index) is lamentable.

The translator has, on the whole, done his work very well, but we wish he had not given the book its title; what is wrong with " Modern Magnetism " ? Further, why should magnetism in general be treated under the strange heading of " Pan-magnetism " ? We realise that the literal translation of " Indifferenzpunkt " is " point of indifference," but we would prefer to see the customary term " neutral point " on page 31. The retention of German characters is inexcusable and irritating and leads in one case to a serious mistake in the equation for the magnetisation of a paramagnetic gas, which will cause confusion to the less advanced reader.

In spite of these faults, however, the book will serve a useful purpose, and we confidently look forward to a future edition in which they will be rectified.

L. F. BATES.

Le mouvement scientifique contemporain en France. Les Sciences Physico-chimiques et Mathématiques. Par GEORGES MATISSE, D.-ès-Sc. [Pp. 319, with 31 figures.] (Paris: Collection Payot, 1925. Price 10 frs.).

THIS little book is of a type quite foreign to English writers. It seeks to give the general reader an idea of the main contributions which eminent French workers have made to the advancement of science in recent years. Since the book deals with the works of some thirty well-known chemists, mathematicians and physicists, naturally, the work of any particular scientist is only briefly outlined. The book is therefore of limited interest to the English reader.

L. F. BATES.

Müller-Pouillet's Lehrbuch der Physik. (Elfte Auflage. Dritter Band—Zweite Hälfte.) Kinetische Theorie der Wärme, von KARL F. HERZFELD. [Pp. x + 436, with 52 figures.] (Braunschweig: Vieweg & Sohn. Akt. Ges., 1925. Price 21 marks.)

IT must be confessed quite frankly that we envy the German physicist his possession of a literature of the type of which this book is so excellent an example. The English literature of modern physics consists of a limited number of monographs dealing with single subjects, a very few Reports published by the Physical Society and the U.S. Bureau of Standards, and a few translations of foreign works, the latter being inevitably somewhat out of date even when they first appear. The reviewer is aware of the existence of only one book by an English writer which gives a satisfactory account of a wide branch of Physics in its experimental, mathematical, *and bibliographical* aspects, such as is provided for us by Prof. Herzfeld's treatment of the Kinetic Theory of Heat. His book is one which will be equally appreciated by the advanced student reading the subject for the first time, and by the research worker desirous of discovering quickly what has been attempted and achieved in any particular part of its field. The author has undoubtedly a better acquaintance with the work done in his own country than that carried out in England; but this really adds to the value of the book to the English reader, for it gives him in convenient form a thorough and comprehensive account of recent work in Germany.

The first chapter contains a good account of the kinetic theory of gases. In addition to the usual mathematical theory there is a description of the experiments which have been devised to test Maxwell's law of the distribution of velocities, and a treatment of the viscosity and thermal conductivity of gases which is quite remarkable for the range of material it includes. There are also short sections dealing with the Knudsen absolute manometer, the diffusion pump, and the Gaede molecular pump. The second chapter is devoted to general statistical mechanics and, since the author has avoided the use of very advanced mathematics, some of the more recent researches of Planck, C. G. Darwin, and R. H. Fowler hardly receive as extensive a treatment as their importance warrants. This omission is remedied to some extent in the penultimate chapter, which deals (in small print) with the elaboration of the statistical method.

The next four chapters deal with gases, solids, liquids, and solutions in the order given. In his discussion of gases the author considers the various factors which produce departures from the characteristic equation of the perfect gas, but does not deem it worth while to deal with the numerous semi-empirical equations which have been proposed to represent the behaviour of real fluids. The chapter on gases also contains interesting sections on the forces between molecules, specific heats, dissociation, and reaction velocity; but the absence of references to English publications is, in this section of the book, rather remarkable.

The treatment of solids includes sections on the properties and structure of crystals, free energy (of solid bodies), vapour pressure equilibrium, fusion, sublimation, and the equation of state. There is a particularly interesting article on the nature of the forces in ionised crystals, but no reference to the recent work of Lennard-Jones on that subject. The chapter on fluids contains a long account of fluid crystals, while that on the theory of solution embraces a wide range of material, including surface phenomena, adsorption, the kinetic theory of osmotic pressure, and the theory of strong electrolytes.

Chapter VII deals with the theory of fluctuations and contains a particularly full account of the Brownian movement. The next chapter contains an account of the postulates of the quantum theory with its applications to the kinetic theory of matter, and finishes with a discussion of the Nernst heat theorem. Finally there is a description of the experimental determination of the Löschmidt number, with sections on the numerical values of atomic diameters and on the history of the development of the atomic theory.

Throughout the book Prof. Herzfeld has taken care to show clearly the physical meaning of the mathematical assumptions and processes employed in the development of the theory, a procedure which adds much to its value to the student, while as a work of reference it must be regarded as indispensable to those whose work brings them into contact with the subjects with which it deals.

L. F. Bates.

CHEMISTRY

The Chemistry of Drugs. By NORMAN EVERS, B.Sc., F.I.C. [Pp. viii + 247.] (London: Ernest Benn, Ltd., 1926. Price 32*s.* 6*d.* net.)

IT is becoming increasingly difficult for the general chemical reader to keep abreast with the subject of the chemistry of drugs, and a book such as the one under review should be welcomed as it claims to deal with all naturally occurring drugs whose active principles are known and all synthetic drugs of practical importance. In writing such a compilation the author is naturally faced with the difficulty of determining how to deal most economically with the limited space at his disposal and what to omit; as a result, the subject of essential oils used in medicine has been treated only cursorily as it is dealt with fully in another book of this series. Again, in describing methods of manufacture, the author has treated chiefly of the chemistry of the methods employed rather than of the technical details, and analytical methods have been entirely excluded as being too large a subject and calling for separate treatment.

The book is divided into two parts, of which the first deals with synthetic drugs; these are classified into groups such as Hypnotics, Antipyretics, Local and General Anæsthetics, Antiseptics, compounds of arsenic and antimony, compounds of mercury, and miscellaneous synthetic drugs. The second part (dealing with drugs of natural origin) is subdivided into two sections devoted to alkaloidal drugs and those not containing alkaloids. This section forms by far the greater part of the book, and contains much of the less accessible information, and is for this reason the more valuable. The book also contains two appendices, the first of which contains a brief account of the difficult subject of the relation between chemical constitution and physiological action, while the second consists of a number of quite useful tables of trade names, botanical sources, etc. It will be seen from the above summary that the author has collected under one cover a very valuable amount of information which should be of great assistance to those wishing to ascertain the essential facts concerning any particular drug without prolonged search through a number of different books.

P. H.

Photosynthesis. The Assimilation of Carbon by Green Plants. By WALTER STILES, Sc.D. (Cambridge). [Pp. vii + 268, with diagrams.] (London: Longmans, Green & Co., 1925. Price 16*s.* net.)

IT has long been known that in the presence of light and chlorophyll the plant is able to build up its carbohydrate from atmospheric carbon dioxide and water, but all attempts to produce carbohydrate outside the plant, by the action of chlorophyll on carbon dioxide and water, have failed, although other methods of producing carbohydrate from these two substances have been devised. There is, then, in the living plant cell some other factor at work which plays an essential, but as yet entirely unknown part, in the photosynthetic process. As the author rightly states, the manufacture of carbohydrates in the green leaf may be regarded as the central fact of life on this planet, and it is the energy stored up in plants by photosynthesis in bygone ages which has rendered possible the industrial developments of the last century. The supply of coal is, however, not inexhaustible, and the utilisation of the radiant energy of the sun is clearly indicated as the means of obtaining further energy for the development of our present civilisation. The scientific study of the photosynthetic process may therefore be of directly practical importance if by a better understanding of the process it became possible to influence the photosynthetic activity of plants. For this reason the volume under review is to be welcomed, since it gives a well-balanced and critical summary of our present knowledge of the subject presented in a manner calculated to arouse interest and to stimulate further research in this fundamental problem. Those interested in the subject will be grateful to the author for the summary he has prepared for them and for the 870 odd references which he has quoted. The book is divided into twelve chapters, and deals in a most complete and systematic manner with all the various aspects of the question. The mode of entry of the carbon dioxide into the plant by gaseous diffusion, the influence of external and internal conditions on photosynthesis, the utilisation of energy in photosynthesis, the mechanism of the relation of photosynthesis to other plant activities, all receive attention, in addition to the chemistry of the assimilatory pigments and the methods of measuring photosynthesis. The book is written throughout in a very clear and lucid style, and is one which will be widely read by students and teachers alike and by all interested in problems of plant physiology. P. H.

Volatile Solvents and Thinners used in the Paint and Varnish Industries (Oil and Colour Chemistry Monographs). By Noel Heaton, B.Sc. [Pp. viii + 158.] (London: Ernest Benn, 1925. Price 15*s*.)

The second of these monographs has been written, according to the preface, with a view to presenting, for reference and comparison, detailed information as to the nature, preparation, and properties of every solvent of industrial importance in the paint and allied industries.

The number and variety of solvents in industrial use are rapidly increasing, and it is a pleasing feature of this book that the author has not confined his attention to those solvents already well known, but has also discussed those which may be of industrial importance in years to come. The properties and uses of each solvent are very fully discussed and standard specifications are given for all the important solvents considered.

A great deal of confusion exists with regard to the names of certain of the petroleum hydrocarbons such as benzine, white spirit, etc., and there is much to commend the author's plea for the abolition of the term "benzine" in favour of "petroleum spirit" qualified by a statement of the boiling range.

Very few errors have been noticed, but one sentence on p. 87 requires revision, and "tinned" on p. 129, line 25, should obviously read "tin." The literature references are very full and amply suffice for the purpose the author has in view. A very useful appendix gives a summary of the principal solvents and their chief properties. It seems a pity not to have included a name index in a work of reference of this kind, especially as names are not included in the index given.

The author has treated the subject in an able manner, giving us a clear, readable account, and the book should be of great value to all connected with the Paint and Varnish industries, to whom the work is principally directed.

T. L. Garner.

The Chemistry of Drying Oils (Oil and Colour Chemistry Monographs). By R. S. Morrell, M.A., Ph.D., F.I.C., and H. R. Wood. [Pp. ix + 224.] (London: Ernest Benn, 1925. Price 21*s*.)

This volume forms a very welcome addition to the library of the oil and colour chemist.

After a brief but interesting historical introduction, the authors follow with a chapter on the component acids of drying oils. It is pleasing to note in this chapter that due importance is given to the work of Müller and Shearer, elaidic and oleic acids being given the trans- and cis-formulæ respectively. Most authors dealing with the fatty acids completely ignore this work. The chapter on the composition of drying oils is particularly good, the literature references being very full indeed; in fact, the latter form a fine feature throughout the book. An account is given of the expression, extraction, and refining of linseed oil, as the typical drying oil, and this is followed by a description of the preparation of boiled oils, etc,, and their uses in industrial processes. The work also includes a chapter on the analysis of drying oils and one of particular interest on "the properties of drying oils from a colloidal standpoint."

The indexing is very good, both subject and name indexes being provided.

It is difficult to criticise so excellent a book, but the chapter on boiled oils was rather disappointing, being somewhat too briefly treated. No mention is made of the work of Wilbuschewitsch, Genthe, and others on the production of boiled oils. It is, however, obviously difficult to treat the mass of information existing on the subject so as to obtain it in a compact enough form for such a monograph.

The book as a whole is excellent, and should undoubtedly have a wide appeal, not only to research workers in this field and to those engaged in the oil and colour industries, but also to those engaged in the kindred industries.

T. L. GARNER.

British Chemicals, their Manufacturers and Uses. [Pp. 262.] (London: Ernest Benn, Limited, for the Association of British Chemical Manufacturers. Price 10*s*. 6*d*. net.)

THE Directory of the Association of British Chemical Manufacturers appears in this new form. It contains, besides a short introduction, a list of the Council, Officers, and Members of the Association, together with a classified list of British-made chemicals and also a select list of those supplied under trade or proprietary names.

The major list is made available for reference by the provision of indexes in French, Spanish, Italian, Portuguese, and German; in addition, a note as to the industrial use of each substance is appended. The whole forms a well-compiled and comprehensive reference book which should prove of great value to buyers in all parts of the world.

From the scientific standpoint it seems a matter for regret that commercial chemical nomenclature does not, even at its best, conform in many cases with that officially adopted by the Chemical Society; discrepancies of this nature should be minimised by giving the correct name as an alternative in every case.

The concluding part of the volume is occupied by "special announcements of the products manufactured by Members," but the uninitiated might be pardoned for mistaking the contents of this section, some 50 pages, for advertisements. Moreover, as the whole publication is in the nature of advertisement, it seems a pity that it has been found necessary to charge a comparatively high price. Certainly it is a well-produced book, but one may express the hope that the judicious placing of many free copies will be of considerable service in assisting the revival of trade in a great industry.

H. J. E.

GEOLOGY

Ammonites from the Upper Kimmeridge Clay. By E. NEAVERSON, D.Sc., F.G.S. Papers from the Geological Dept. of the University of Liverpool. [Pp. 52, with 4 plates and 2 text-figures.] (Liverpool: University Press; London: Hodder & Stoughton, Ltd., 1925. Price 10*s*. 6*d*.)

IN this memoir the ammonites of the Upper Kimmeridge Clay are described for the first time. Three different stocks are present, represented in the lowest zone considered (*Virgatosphinctoides wheatleyensis* — *Aulaco-*

sphinctes- and *dorso-planus*-zones of Buckman) by the genera *Virgatosphinctoides, Allovirgatites,* and *Sphinctoceras.* At various horizons up to the *pallasianus*-zone *auctt.* these stocks branch off lineages which, in many cases, are homœomorphous one with another. To these lineages the author gives generic names. The reader is grateful to Dr. Neaverson for his indication (p. 9) of the phylogenetic connotation of the generic names " in view of the great influence of the personal equation upon the institution of new genera and species," and in view, it may be added, of the regrettable tendency shown recently by some systematists to establish " new " genera and species without adequate diagnoses, to say nothing of definitions of " genus " and " species " in the authors' conception of these terms.

The systematic results of Dr. Neaverson's phylogenetic study of the ammonite fauna rendered necessary a revision of the zonal nomenclature of the Upper Kimmeridgian. New zonal indices, which need not be detailed here, have been chosen for the main horizons, except the *pectinatus*-zone and the " Portland Sands "—a term which Dr. Neaverson suggests should be dropped, in view of the Kimmeridgian affinities of the fauna, and the clayey facies in the Kent borings. Use and wont, however, will probably perpetuate a designation which is indefensible on palæontological grounds, and not always applicable lithologically.

Judging from descriptions and figures and his own small collection of ammonites from the Upper Jurassic of Boulogne, the author believes that these forms have close affinities with those of equivalent horizons in the English Upper Kimmeridgian, and not with forms from the Lower Volgian of Russia, with which the ammonites of the Anglo-Gallic province have previously been identified, on the basis of superficial resemblance. The author's work on the ontogenies of Upper Kimmeridgian forms has shown that they run an entirely different developmental course from the Russian *Virgatites.*

According to R. Douvillé the Russian *Virgatites* fauna is derived from *Ataxioceras* by migration from the Mediterranean area, via the Caucasus. Dr. Neaverson thinks the Upper Kimmeridgian fauna of the Anglo-Gallic area may also have had its ultimate origin in the Mediterranean province. As the author insists, however, a complete revision of the South European ammonites must be undertaken before the truth of this speculation can be established. All that can be said of the immediate origin of the Anglo-Gallic ammonite fauna of the Upper Kimmeridgian is that it is probably derived from the fauna of the Brittany region (the probable source of the materials of the Kimmeridgian sediments, as revealed by petrographic examination), through the northward drifting of the planktonic young. Of greater importance is the fact that the author has established proof of the existence of two distinct zoogeographical provinces in Northern Europe in Upper Kimmidgian times, suggesting a continuance of the palæogeographical conditions which restricted the distribution of the earlier *Gravesia* fauna to the Western European province.

JOHN WEIR.

BOTANY

A Class Book of Botany. By ERNEST STENHOUSE, B.Sc. [Pp. xi + 514, with 363 text figures.] (London: Macmillan & Co., 1925. Price 7*s.* 6*d.* net.)

A TEXTBOOK intended for students preparing for matriculation, school certificate, senior local and similar examinations. A special point is made in having the practical lesson before the theoretical work, a method which in the reviewer's opinion will be difficult to carry out in practice because of the time required for such a procedure. The book is fully illustrated by means of drawings and reproductions from photographs; some of the latter, *e.g.* figs. 85 and 206, are too small to adequately serve their purpose and a number, *e.g.* figs. 124 and 177, are lacking in contrast.

The numerous experiments are well chosen and the dividing of the book into headed paragraphs will help the student in his reading. Further assistance is given in the form of questions, some original, others from papers set in well-known examinations, appended to each chapter. E. M. C.

Monocotyledons. A Morphological Study. By AGNES ARBER, M.A., D.Sc. [Pp. xvi + 258, with frontispiece and 160 figures.] (Cambridge: at the University Press, 1925. Price 21*s*. net.)

THE authoress begins with a thoughtful chapter on the principles of morphology, in which she expresses the opinion that applied morphology still finds its most hopeful field in the comparatively modest task of pursuing that study of the differentiation process which was begun by de Candolle nearly three hundred years ago. She naturally expresses disagreement with the reviewer's conclusion with regard to petiolar structure, that "it is to function rather than to phylogeny that we must look for its elucidation." But in stating that the adaptational changes to which attention was drawn were purely numerical and quantitative, Mrs. Arber is scarcely accurate, for it was pointed out that in peltate and pseudopeltate leaves the bundles were very commonly arranged in a ring instead of in an arch, consequently some of the bundles exhibit that inverted orientation to which Mrs. Arber attaches so great an importance.

To those familiar with the writings of the authoress, the present pages offer few surprises. But to others the title of this volume may raise expectations that the text does not fulfil. The sub-title is scarcely more illuminating, since a considerable proportion of the subject matter appertains to anatomy. As is rightly held, external form is in large part correlated with internal constitution, and hence the grosser anatomical organisation, especially in relation to the distribution of the vascular tissues, is appropriately described and copiously figured.

Consideration of the leaf, its modifications and its interpretation as a phyllodic structure, constitute the theme of nearly half the text and a large proportion of the illustrations. Of the remainder, the chapters dealing with the root and the shoot form the largest share, whilst smaller sections deal with the reproductive organs, seedling structure, and various topics such as parallel evolution and taxonomy.

The treatment of the floral morphology, on the grounds of the availability of information on this subject elsewhere, is of a very abbreviated and particularised character, and perhaps constitutes the chief indictment against so generalised and misleading a title. But if the reader suffers some disappointment from unrealised expectations on the one hand, he will, on the other, be fully repaid in the perusal of these pages by the clarity of the descriptions and the charm of Mrs. Arber's style. The wealth of illustrations, of which the number of figures gives no indication, is so great as to become almost an embarrassment of riches in which the reader is sometimes at a loss to disentangle the essentials.

Mrs. Arber's extensive study of this group has led her to support the concept of parallel evolution and to emphasise the importance of what the reviewer has elsewhere termed the "momentum of evolution" as being a characteristic as significant in the diagnosis of a race as its morphological or chemical features. Altogether these pages are full of suggestive interest, both with regard to special interpretation and topics of a more general character. E. J. S.

An Introduction to Plant Anatomy. By A. J. EAMES, Professor of Botany, Cornell University, and L. H. MACDANIELS, Professor of Pomology, Cornell University. [Pp. xiv + 364, with Frontispiece and 146 figures.] (London: McGraw-Hill Publishing Co., 1925. Price 17*s*. 6*d*. net.)

THE works in English dealing with plant anatomy are extremely few, and of these, some like de Bary's *Comparative Anatomy* and Haberlandt's *Physiological Plant Anatomy*, of which the English editions appeared respectively in 1884 and 1914, need revision in the light of recent research. Others, such as Solereder's *Systematic Anatomy of Dicotyledons*, treat the subject from a special aspect. A general textbook of Plant Anatomy, even of an elementary character, is, therefore, heartily welcome, and the authors of the present work have produced a clearly written and not too lengthy account which should serve admirably as an introduction to more specialised study, for which provision is made in the bibliographies appended to each chapter.

The subject matter begins appropriately with the cell and its modifications; the meristems; the various types of tissue and the primary plant body. From these one passes to the consideration of the secondary structure and the anatomy of the diverse organs; ecological anatomy and the historical aspect of the subject.

The intention of the authors was avowedly to write an elementary account in the production of which opinions will necessarily differ as to what ought to be included and what omitted. The organisation of Angiosperm tissues is admirably presented, but Gymnospermous structure is treated very briefly, whilst that of the Pteridophytes receives but the scantiest attention. The chapter on ecological anatomy, like some others, might have been usefully expanded, and one may perhaps doubt whether the structure of recent types can be properly appreciated in its true perspective without some knowledge of the anatomy of the plants of the past. Nevertheless, the student who assimilates the substance of these pages will have laid a sound foundation for future study.

Most of the illustrations are original and comprise numerous line-drawings and a considerable proportion of excellent half-tone reproductions of photomicrographs.

E. J. S.

Spitsbergen Papers. Vol. I. Scientific Results of the First Oxford University Expedition to Spitsbergen (1921). [Pp. xi + *ca*. 450, with figures and plates.] (Oxford University Press, 1925. Price 30*s*. net.)

THIS is a useful assemblage of the reprints of papers produced as the outcome of the Oxford expedition to Spitsbergen, and will be welcome by all those interested in Arctic exploration.

The total number of papers is thirty-three, if we include a short appendix. These are of varying length, the shortest being by no means the least important. The majority deal with various animal groups, ranging from Land-mites, Protozoa, and Rotifiers, to Parasitic Worms and Saw-flies. Seven papers treat of the habits of birds, and there is a useful attempt to correlate the plant and animal communities. There are five purely botanical contributions, of which four are concerned with cryptogamic groups. In addition, there are three papers devoted to the geological and topographical features of the areas visited.

With this variety of material before one it is impossible in the space at our disposal to give any idea of their separate contents, but we may note that the taxonomic results embrace seven new species of Diptera, one of Collembola, one Spider, five new Land-mites, one new Rotifer, one Cestode, and one Alga. The additions to the pre-existing lists for the area are considerable;

but far more important are the data obtained regarding the habitats and mode of life of the plants and animals, which together constitute an important contribution towards the ecology of arctic lands.

E. J. S.

Soil Characteristics. A Field and Laboratory Guide. By PAUL EMERSON, Ph.D. [Pp. x + 222.] (London: McGraw-Hill Publishing Co. Price 12*s.* 6*d.* net.)

IN the present volume the author has put forward a useful compendium of methods used in soil investigation, no attempt being made to demonstrate the features of particular types of soil. The opening section is of a general nature, dealing with the classification and mechanical analyses of soils, and giving a full outline of the procedure followed in making soil surveys, together with methods of sampling and the precautions that must be observed. Under the somewhat misleading heading of soil fertility are conveniently grouped together analytical methods for the determination of various soil constituents, the exact procedure being fully indicated in each case, a valuable aid to the student. Much space is devoted to details of preparation of equipment, and there is, in addition, a collection of formulæ and calculations that are in constant use. Soil physics and soil microbiology are dealt with less fully, the latter giving first a general survey of methods of determining bacteria, protozoa, and fungi in soil. Chemical studies of the activities of micro-organisms lead up to means of demonstrating the biological action of nitrogen, carbon, and sulphur organisms on their appropriate compounds.

The majority of the references are to American papers, as these are the most accessible to American students, though others are included where necessary, and all are placed at the end of their special sections. Throughout the book supplementary laboratory experiments are freely suggested, with the idea of providing students with a sound working knowledge of the means of determining the characteristics of whatever soils may have to be considered.

W. E. BRENCHLEY.

ZOOLOGY

Principles of Genetics. An Elementary Text, with Problems. By EDMUND W. SINNOTT and L. C. DUNN. [Pp. xviii + 431.] (London: McGraw-Hill Publishing Co., 1925. Price 17*s.* 6*d.* net.)

THE authors state in their preface that " the object of the present volume is to set forth the essential principles of genetics in as clear and concise a manner as possible." They have certainly been most successful. The whole book is " readable," and it is not often that accounts of complicated genetical experiments are to be found that can be read with any ease. Usually a considerable effort is required to understand them. Each problem has been dealt with in simple terms and concisely, but it is in the selection of the illustrations that the authors are to be most congratulated. With the judgment of experienced teachers of genetics, they have devised just those illustrations necessary to bring out their essential points and to bind the book together in one readable story.

The treatment of the subject follows the usual lines. After two introductory chapters, Mendel's Laws of Inheritance are dealt with. This leads on to Linkage and the Chromosome Theory of Inheritance. After this, the problem of sex and its inheritance is dealt with. Here the question of the physiological aspects of sex and sex-reversal might have been dealt with at greater length. The last part of the book is devoted to the practical applications of genetics and to a consideration of the problem of Eugenics.

At the end of the book there is a useful bibliography, but it contains a strange omission due, no doubt, to an oversight. It does not mention any of the works of Leonard Doncaster.

Each chapter of the book is followed by a list of questions and suggestions for further reading, which will certainly be of use to teachers of the subject.

The Ascent of Man. By ALFRED MACHIN. [Pp. xix + 325.] (London: Longmans, Green & Co., 1925. Price 7*s.* 6*d.* net.)

THE main object of this book is "an investigation of the theory of natural selection in the hope of discovering why it breaks down at the human race, and of seeing whether it is, in fact, capable of explaining the *modus operandi* of human development." The author devotes the first two parts of the book to pointing out "a fundamental error in Darwin's hypothesis." He states that Darwin considered that redundant reproduction caused a struggle for existence and resulted in Natural Selection. He disagrees with this on the ground that reproduction cannot become redundant, as, if it did, it "must tend to be reduced by Natural Selection until it becomes fitted to the needs of the race." He thus cuts out the first term and states simply that a struggle for existence gives rise to Natural Selection. The struggle for existence is taken simply as a fact of observation. "What is its fundamental cause is unknown."

The whole of the author's argument is, apparently, based on a misconception of the terms used by Darwin. He complains that Darwin's phrase "Struggle for Existence" is incomplete. "Nature is as much concerned for the reproduction of the individual as for the continuance of the individual's existence." But Darwin stated in *The Origin of Species* that he used the term "in a large and metaphorical sense . . . including . . . success in leaving progeny." Again, he uses the word "redundant" in a very limited sense, and certainly not in the manner used by Darwin. He maintains that if an animal produces a large number of eggs just sufficient in quantity to maintain the number of the species, then that number is not redundant, and in one sense he is correct; but Darwin most certainly did not use the term in this sense when he referred to "the redundant power of reproduction which inevitably leads to a struggle for existence." The number is not excessive if the end result only is considered, namely the fact of replacing the parents, but inasmuch as the number greatly exceeds the number of parents, it *is* redundant. All the large number of offspring of any pair of parents vary among themselves. They are all striving to live, to function properly, and those most fitted for this functioning will, according to Darwin, be those that will survive to replace their parents. This is what Darwin referred to as one of the cases of a "struggle for existence," and if the author had clearly understood this he would have realised the sense in which Darwin used the term "redundant."

The last part of the book deals with the evolution of modern man and civilisation in the light of this revised conception of Natural Selection. It is of interest in that it emphasises the importance of economic and religious factors in the development of modern civilisation; but, unfortunately, it is in parts both erroneous and antiquated. Thus in at least three places it is stated that the main difference between mammals and reptiles is that the former care for their young while the latter do not. The fact that the mammals have a high and steady body temperature is not mentioned. Again, it is stated that the chief distinction between man and the anthropoid apes is that man has two feet in place of two hands. The work that has been carried out of recent years on the evolution and characteristics of the human brain is not mentioned. On p. 241 religion is defined in a manner that would not please the author of *The Golden Bough*, and, in fact, the evolution of religion from magic is completely ignored. Lastly, on p. 290 there is the statement that—*mirabile dictu*!—it is the mothers only "who transmit the physical and emotional characters and instincts that are in the blood." What "that are in the blood" means is not explained, but it is at least pleasant to think that there is one man who has not heard of a chromosome.

H. G. C.

Evolution and Genetics. By THOMAS HUNT MORGAN. [Pp. ix + 211.] (Princeton: Princeton University Press; London: Oxford University Press, 1925. Price 9*s*. net.)

THIS small book is described by the author as "an attempt at a critique of the Evolution Theory," in which special attention is paid to "the bearing of the recent discoveries in genetics and in mutation" on the problem. It is always a pleasure to be able to find collected together in a concise and readable form the most recent views of so undoubted an authority as Prof. Morgan on his own subject. Prof. Morgan has expressed his views very clearly, and in a very simple manner, using only the simplest examples as illustrations.

After dealing briefly with the history of the Evolution Theory, and then describing the evidence for organic evolution, the author devotes a chapter to the Materials of Evolution. Here the question as to what constitutes a species is discussed at some length. Prof. Morgan cannot accept Mr. Bateson's view that "the production of an indubitably sterile hybrid from completely fertile parents" would mark a critical advance in the solution of the problem of the origin of species. He puts forward the view rather that in the formation of new species some sort of isolation is needed—a view that will be dear to many Lamarckians. This isolation would result in many kinds of mutational differences and apparently interspecific sterility would result from these. It seems a pity that, as the rest of the book is devoted to discussing the bearing of recent Mendelian and other experimental work on the problem of the origin of species, Prof. Morgan was not able to put forward some more satisfactory criterion of species.

A chapter is devoted to the question of the inheritance of acquired characters, and this is the most unsatisfactory part of the book. It is so biased in favour of their non-inheritance that readers can hardly be expected to accept it as a critical survey of the problem. Thus Prof. Morgan quotes Pawlow's account of his work on the inheritance of conditioned reflexes in white mice. Whether Pawlow's work will be found to be correct or not, it seems a pity that Prof. Morgan, having, as he admits, no direct evidence against the work, suggests that, if it is true, "we might soon look forward to the day when the ringing of bells would endow our great-grandchildren with all the experience of the generations that had preceded them." It can only be surmised that Prof. Morgan is unacquainted with the extremely difficult technique of establishing a conditioned reflex. Prof. Morgan also makes no mention in this chapter of the recent work on the evolution of the human brain. There are many in authority who consider that this work throws a completely new light on the question of the inherited effects of use and disuse; but perhaps Prof. Morgan would not consider evidence from comparative anatomy permissible in the discussion of this subject. Is it not time that someone put forward the suggestion that some acquired characters *are* inherited, while other characters are not "acquired," but are also inherited? The very diversity of the nature of characters would suggest that this is the most profitable view to adopt.

PALÆONTOLOGY

Textbook of Palæontology. By KARL A. VON ZITTEL. Vol. III, Mammalia. Revised by MAX SCHLOSSER, Ph.D. Translated under the direction of CHARLES R. EASTMAN, Ph.D. Translation revised, with additions, by SIR ARTHUR SMITH WOODWARD, F.R.S. [Pp. viii + 316, with 374 illustrations.] (London: Macmillan & Co., 1925. Price 25*s*. net.)

DR. EASTMAN'S version is a literal rendering into English of Dr. Max Schlosser's revised account of the Mammalia in Zittel's *Grundzüge der Paläontologie.* In completing the work, left unfinished by Dr. Eastman's death in 1918, Sir Arthur Smith Woodward has included the most important recent discoveries, and has extended the bibliographies to include later literature.

The plan of the work differs in no essential respect from that adopted by Dr. Schlosser in the 1923 edition of the *Grundzüge.* Squalodontid and delphinid whales are treated as families of *Odontoceti, Pyrotheria* as a suborder of notoungulates; the Primates are described under the suborders *Prosimia* (*Lemuroidea*), *Anthropoidea*, and *Bimana* (*Hominidæ*).

The work is uniform with Vols. I and II of Dr. Eastman's translation, and maintains the very high standard of this remarkable series.

JOHN WEIR.

MEDICINE

Louis Pasteur. By S. J. HOLMES, Ph.D. [Pp. iv + 246.] (London: Chapman & Hall. Price 7*s*. 6*d*. net.)

IN adding yet another to the number of books on Pasteur, the author does not claim to make any new contribution to his subject. Maintaining, as he does, that Pasteur's work cannot be too widely known, he restates in simple terms that series of brilliant discoveries which have made his hero's name a household word. The interpolation of a chapter on micro-organisms at an early stage of the book renders it possible for the reader with little or no technical knowledge to follow the master's achievements as here presented. Such a reader will appreciate the sequence of work that seems to follow as the logical result of the researches on crystallisation, the later developments coming with a certain inevitableness as problem after problem presented itself for solution.

The author's further claim that he has presented an idea of Pasteur's personality cannot be conceded. Such presentation as there is depends mainly on quotations from letters and speeches, many of them couched in the formal terms associated with addresses of welcome. And it is because the description of his work is adequately done, whilst that of his personality fails, that the casual reader may obtain the impression that Pasteur lacked some of those qualities which made him one of the most lovable as well as one of the most brilliant men that France has produced.

H. J. E.

Organic Medicaments and their Preparation. By ERNEST FOURNEAU. Authorised translation by W. A. SILVESTER. [Pp. x + 262.] (London: J. & A. Churchill. Price 15*s*. net.)

DURING the last ten years considerable attention has been given in England to the manufacture of organic drugs, and as a consequence the theoretical and practical aspect of the subject is now receiving more attention from teachers and students. This excellent book, originally published in Paris in 1921, is now available for all English-speaking readers and should serve to bring a greater number into touch with the branch of organic chemistry with which it deals. It had its origin in a course of lectures given in Madrid by M. Fourneau about eight years ago, and this course is now presented in crystalline form. This last expression is used advisedly in view of the concise and logical method of dealing with the subject. Naturally one does not expect a complete treatise; certain sections of drug chemistry are altogether absent, but the book possibly gains in value as a result.

The theoretical section is of no ordinary type; excursions into pharmacology, works costs, and other subjects render it of unusual interest. It covers ground which is common to more than one science whenever such extension of the main subject is useful. On the practical side a series of preparations is given: many of these will be new to the average student, and might well replace on occasion some of the older exercises which deserve a well-earned rest.

Mr. Silvester's translation is eminently satisfactory: the few errors in the original French edition have been corrected and some notes on more recent work added.

H. J. E.

The Erythrocyte and the Action of Simple Hæmolysins. By Eric Ponder. [Pp. x + 192.] (Edinburgh and London: Oliver & Boyd. Price *12s. 6d.* net.)

The editors of the Series of Biological Monographs and Manuals, of which this is No. II, have rightly gauged the interest which is being shown more and more, both by the lay public and by those whose scientific work lies along other lines, in the results obtained "in the field of general physiology and of experimental biology and in the application of biological principles to economic problems," as is shown by the list of the volumes of the series.

The volume under review is one which more particularly carries out their second aim, to provide monographs by the specialist which shall supplement the general knowledge which is all that workers even in a related field may have of a particular part of a subject in these days of extreme specialisation. The book is divided into two parts, the first covering the morphology, chemistry, and structure of the erythrocyte, the second discussing the action of simple hæmolysins. It is very definitely a presentation of the author's own work in this special field, and has been made the occasion of a critical survey of the work of others in the same field.

This plan does not detract from the enjoyment of the first part, which, with its collection of data and its account of the author's work, is remarkably useful and interesting. But in the second part, where admittedly the author is dealing with a subject whose investigation is beset with pitfalls, this element of criticism is so conspicuous as to overweight the genuine interest of the results described, and so to leave on the reader's mind an impression that the amount of destructive force employed is not balanced by the amount of work achieved.

W. C. Cullis.

Physiological and Clinical Chemistry. By W. A. Pearson, Ph.C., Ph.D., M.D., and J. S. Hepburn, A.M., B.S., M.S., Ph.D. [Pp. xvi + 306, with 30 illustrations.] (Philadelphia and New York: Lea and Febiger, 1925. Price $4.)

This book suffers from the defect of representing but one of a series of courses in chemistry given to the same students. Its edges are ragged. Thus the introductory chapter on organic chemistry is little more than a dictionary of substances of physiological and clinical interest, and the chapters on carbohydrates and proteins, though more extensive, have scarcely achieved a happy solution of the old problem of the amount of theoretical discussion which should be introduced into a practical textbook. A judicious curtailment of some of the ramifications of the text would have permitted a needed elaboration of detail in both theoretical and practical description. On the other hand, the book is interleaved with blank pages—a provision which bespeaks a real sympathy for the harassed medical student—so that it may be the intention of the authors to pass on to the reader the responsibility for elaboration.

The experimental work detailed on tissues, enzymes, digestion, blood, urine, fæces, and foods is adequate and includes some novel and probably sound departures from conventional curricula. Quantitative methods have been chosen, not for their intrinsic instructive value, but rather for their simplicity and convenience to routine clinical demands.

Recent years have provided us with a choice of books whose object is to equip the reader with sufficient empirical technique for the routine requirements of medical practice. The present volume is as satisfactory as its predecessors in this purpose. The student who seeks in chemistry a scientific culture which will enlighten his studies of medicine will be less satisfied. He is not likely to be put off with such picturesque absurdities as the following quotation: " The composition of the adult human body corresponds to 1,000 eggs or 38 quarts of water; 60 lumps of sugar; 20 teaspoonfuls of salt; iron enough for 7 spikes; . . . enough graphite to make 10,000 lead pencils; phosphorus enough for 800,000 matches; besides 3,500 cubic feet of gas. . . ." We would like to excuse this as mere playfulness.

R. K. C.

Food and Health. By R. H. A. Plimmer, D.Sc. (Lond.), and Violet G. Plimmer. [Pp. 64, with coloured frontispiece and diagrams.] (London: Longmans, Green and Co., 1925. Price, paper cover 2*s*., cloth cover 3*s*. 6*d*., Food Chart 3*d*.)

This modest little book sets out to tell " the principles which should guide the selection of food and to point out which foods should be eaten and why others should be avoided." It is essentially a brief popular version of the authors' more comprehensive treatise on the vitamins. The argument is written round a geometrical materialisation of the principles of dietetics in the form of a simple coloured diagram. Distortions of the symmetry of this become the symbols of various departures from the squareness of a " square meal." It is doubtful if the general reader will regard as a complement the constant intrusion of this diagram into a text which itself presents no intellectual difficulties. But, perhaps, the cross-word puzzle has created an appetite for such diversions.

Few will disagreee with the contention that there is wisdom in taking thought of what we shall eat. Many may even agree that civilised man has lost all instinct for the proper choice of food. Amongst these latter we shall expect to find the more ardent disciples of " the square meal."

R. K. C.

MISCELLANEOUS

Mere Mortals. Medico-Historical Essays—Second Series. By C. MacLaurin, M.B.C.M., F.R.C.S.E., etc. [Pp. 276, with 8 portraits, undated.] (London: Jonathan Cape.)

An attempt to make a diagnosis, but only from such signs and symptoms as remain in the memory of history, in the medical cases of Samuel Johnson, Henry VI, Henry VIII, Edward VI, Mary Tudor, Elizabeth, Ivan the Terrible, Luther, and others, including Nietzsche, Schopenhauer, and Spinoza. The author is conscious of the frequent scantiness of existing evidence, but does his best to trace the pathological causes of conduct in his subjects, and, so far as we know, his attempt is a novel one. Medical readers will often tend to doubt his conclusions—though not his wit and originality. For instance, if such a slow-spreading disease as syphilis came from America in the reign of Henry VII, it could scarcely, by ordinary chances, have so quickly reached such a high person as his son, Henry VIII, as the author maintains. We doubt that "in 1550 everybody was suffering from syphilis" (page 77). After all, bluff King Hal had three children, one of whom proved to be perhaps the most capable sovereign we ever had, and we seem to remember that Roman history was not wanting in examples of corpulence and other defects equal to his. Use has been made of a series of articles on Royal Death-Beds which appeared in the *British Medical Journal* for 1910. There is a chapter on epidemics. Malaria may have been responsible for the fall of Greece, but scarcely for that of Rome (page 226). We have our doubts, too, about the destructive influence on civilisation alleged against many of the great diseases, including plague and syphilis: nations can apparently acquire at least partial racial immunity against almost any disease; and we are especially sceptical regarding the syphilis bogey, though many doctors now display it vividly to terrified patients. The book is, however, much more suitable for medical than for lay readers. It can be recommended to the former for its scientific interest and to the latter for its general appeal.

R. R.

The Travel Diary of a Philosopher. By COUNT HERMANN KEYSERLING, translated by J. Holroyd Reece in two vols. [Vol. I, pp. 336.] (London: Jonathan Cape, 1925. Price 36*s.* net.)

THIS first volume is alleged to deal with the author's travels in Ceylon and India, but is chiefly concerned with mere reflections which might have been made anywhere, put together without dates or itinerary and with little topographical description, so that the name "diary" is scarcely justified. The word "philosopher" has now also become almost too nebulous for use; and in fact the book is really a collection of miscellaneous opinions set forth at great length. It is Germanic, arrogant, and dull, and in spite of occasional interesting passages, we soon begin to question the author's final judgments. He is severe on the English (page 69), but recognises "their superiority over the other peoples of Europe. . . . They alone are really perfect in their way amongst all Europeans [sic]." Then he talks of "the infinitely richer nature of the German"—we doubt all these propositions. He expatiates at great length on the Buddhist and Hindu religions, rites, and philosophies; but it is difficult to review his conclusions, because we can never quite ascertain what they are. For instance, he says (page 57), "How infinitely more easy it is for the inhabitants of the tropics to evince profound religious thought than it is for one of us! Of course, no concept is necessarily related to its metaphysical reason: Buddhism is right. The Westerner, however, is organised physiologically in such a manner that he cannot recognise this truth without further ado. He is too much entangled in the realm of appearances to attain the necessary distance for judging them. . . . How infinitely better off are the inhabitants of the tropics! They do not need to search for correspondingly exact expression; every form, or none at all, suits them. For, thanks to their mere physiology, they are conscious, as a matter of course, of the very things which, among us, are only revealed to an exceptional mind"—such, we suppose, as the author's. What really does he mean by all this! Each of these sentences is capable of half a dozen interpretations according to the senses in which the words may be taken. Words, words, words! German philosophy, having loaded the world with ambiguities for nearly two centuries, will now doubtless fall at the feet of Buddha and Vishnu or even ascend to the heights of the African Ju-Ju! There is no reality in all this. The barbaric mythologies which the author attempts to revise are merely the ecdyses—the cast-off skins—of the human mind in its way towards the only sound faith, that of scientific process, which is possible to the intellectual imago.

R. R.

Matter, Man, and Mind. By W. F. F. Shearcroft. [Pp. 191.] (London: Ernest Benn, 1925. Price 8*s.* 6*d.* net.)

The alliterative title of this book suggests a discussion between monism and dualism, or at least an essay on the nature of mind; and as most of the chapters possess fanciful titles such as "Primordial Mud" and "Bottled Sunshine," the prospective reader can form no accurate survey of the work by looking at the Contents, and may indeed say rude things about it in his haste. It is really a brief but excellent abstract of the more recent conclusions of science, made for the instruction of those who cannot follow the innumerable paths of research for themselves. It contains some conclusions of an ultra-scientific nature with which few scientists will agree; but as a rule the author keeps to the high road and guides the tourist skilfully along that wide but sometimes winding way.

R. R.

A Course in Philosophy. By George Perrings Conger, Ph.D., Assistant Professor of Philosophy, University of Minnesota. [Pp. xii + 603.] (London: G. Bell and Sons, Ltd., 1925. Price 15*s.* net.)

This very substantial *Course in Philosophy* embodies an attempt to write a more comprehensive and more constructive introduction to philosophy than any of the other books now available. Dr. Conger has certainly planned it in grand style. The work consists of three parts—topical, historical, and analytical. The aim in Part One is to raise questions and to show how philosophical problems arise in connection with various studies, literary, artistic, moral, economic, scientific, and religious. Part Two consists of a brief survey of the history of philosophy, from its beginnings to the present day. Part Three gives an analysis of philosophical theories, and is divided into four divisions devoted respectively to Epistemology (or Theory of Knowledge), Metaphysics (or Ontology), the Normative Disciplines (Ethics, Logic, Æsthetics, and their bearing on various problems), and Philosophy of Religion. The volume also contains three appendices, in the first two of which Dr. Conger gives the main outlines of his own philosophy, while the third presents a list of about a hundred volumes constituting a working library of philosophy. Throughout the volume, moreover, there are given full bibliographies relating to the literature on the problems discussed in the various chapters.

Dr. Conger's elaborate scheme must have involved much thought and labour; and his book will probably be found helpful by some people, especially teachers. But the actual execution of Dr. Conger's plan leaves much to be desired. The author has really attempted much too much. The general treatment is so slight and scrappy as to make the volume appear pretentious; and the bibliographies are almost the best part of the book.

A. Wolf.

Statistical Methods for Research Workers. By R. A. Fisher, M.A. Biological Monographs and Manuals. [Pp. viii + 239, with 6 tables.] (Edinburgh and London: Oliver and Boyd, 1925. Price 15*s.* net.)

Mr. Fisher has undertaken the very difficult task of attempting to put before research workers in biology and agriculture, who are without any special mathematical training, a summary covering a great range of methods and results in the mathematical theory of statistics. The book is chiefly concerned with the best methods of handling small samples, and purposely no general attempt is made to supply proofs of the results quoted, but forty-five examples are worked out fully in the text illustrating different methods of attacking a variety of problems. After conscientiously working through the examples, the student should feel able to apply the methods to exactly similar problems, but it appears a little doubtful whether without a thorough grasp of the underlying principles he could be safely trusted to tackle other problems where the conditions are somewhat altered. This is of course a criticism which applies to all books that attempt to provide a short cut to advanced results by avoiding a thorough grounding in the elements.

From the theoretical point of view it is necessary to read the book in conjunction with the author's papers published elsewhere, and one must confess to some difficulty in following several of the proofs based on the idea of degrees of freedom which appear to rest on arguments from analogy. Again, a long-established method such as the use of the correlation ratio is passed over in a few words without adequate description, which is perhaps hardly fair to the student who is given no opportunity of judging its scope for himself.

But if old methods are dismissed somewhat summarily there are several fresh results of considerable interest as well as new tables, and anyone interested in the theory of small samples can hardly pass over Mr. Fisher's contribution to the subject.

E. S. P.

Population. By A. M. Carr-Saunders. [Pp. 111.] (London: Oxford University Press, 1925. Price 2*s.* 6*d.* net.)

It is often assumed that, in the history of mankind, an increasing population is the normal state of affairs, and that this increase must inevitably continue until, as the pessimists predict, some terrible calamity falls upon an over-stocked world no longer able to support itself. The short but suggestive survey that Professor Carr-Saunders provides in this book helps us to take a wider view. We have of course no direct evidence from prehistoric times, but arguing from observations made on primitive races of hunting and agricultural people existing at the present day, it seems probable that throughout the long run of man's history a stationary population has been the usual thing. Even in historical times, if we consider our own country, the increase in population between the Norman Conquest and the end of the eighteenth century was very slow compared with the increase of the past hundred years. In considering the growth of any population, it is necessary to distinguish between the theoretically possible increase based on the enormous potential fecundity of man, the actual possible increase which will allow a population just not to starve, and the desirable increase leading to that optimum density which allows the average man to obtain the best living which his particular stage of civilisation can provide. From a review of the historical evidence the author comes to the conclusion that in the past the growth of population has on the whole approximated to the desirable rather than the possible increase. In prehistoric times there was for centuries little increase in knowledge of methods of production, and the density of population probably remained almost stable; in the historic period in Europe man's increasing power of production on the whole kept pace with the increase in the population; and even the enormous increase which has occurred in this and other countries during the last hundred years following the industrial revolution can be looked upon as having only kept pace with the requirements of the situation.

But if a population is to be kept at its optimum and not its maximum possible density, a limitation in increase will always be necessary except under certain peculiar and temporary conditions. In early times the checks were found in the practice of tribal customs followed by man without full consciousness of what he was doing—in abortion, infanticide, and abstention from intercourse—while in later Christian Europe pressure of circumstances encouraged the postponement of marriage and at the same time ravages of disease played a powerful if irregular part. And now after a short period of almost unrestricted increase, the growing practice of " birth control " is perhaps a sign that man is groping with a greater consciousness for some new " tribal custom " to meet the old need which must always be present, of keeping the density of population within bounds. The problem bristles with difficulties, for there is such a thing as quality as well as quantity of a population, and there are the relations between nations as well as between the classes within a nation to be considered; but the more it is thought of and discussed the more readily will a solution be found. And without doubt the survey in this little book serves to put the matter in its true perspective. E. S. P.

Genetic Studies of Genius. Vol. I.: **Mental and Physical Traits of a Thousand Gifted Children.** By LEWIS M. TERMAN and Others. [Pp. xv + 648.] (Stanford, California: Stanford University Press, 1925. Price $5.00.)

THIS book is the first of a number of volumes which Dr. Terman and his collaborators hope to publish, describing the progress of an interesting investigation regarding the mental and physical characters of some 1,000 gifted children. The scope of the undertaking is indicated by the fact that the cost of the work already carried out has amounted to about $50,000. The most important part of the inquiry deals with 643 boys and girls mainly between the ages of six and thirteen, selected by their high scores in Stanford-Binet Intelligence Tests and believed to be representative of the most gifted children in the State schools of a number of Californian towns. Nearly all the children obtained an Intelligence Quotient score of over 140, which is reached in an unselected population by about 1 child in 200. Very detailed information was collected for each of the selected children; the results of intelligence, educational, and general knowledge tests; the children's statements as to amusements, hobbies, games, etc.; independent scalings by parents and teachers of physical, mental, social, and moral traits; medical information and anthropometric measurements; details regarding home conditions, profession of father and records of ancestral ability. Similar information was available or specially collected for various control groups of unselected children.

The labour involved must have been very great, but even then, when divided into sexes and subdivided into age groups, 643 children are not sufficient to provide any certain measures of the correlation between different physical and mental characters—a fact which is perhaps not sufficiently realised by some of the contributors, who appear too ready to draw conclusions from mere percentage comparisons based on very small numbers. But, taken as a whole, the general run of the results provides definite information as to the general characteristics and personal traits of the upper ½ per cent. of children measured on the Stanford-Binet Intelligence scale, and shows that these children are not only intellectually but also to a smaller degree physically above the average; that this superiority is usually evidenced at any early age, and appears to have nothing to do with the amount of schooling; and, further, that there is distinct evidence for the hereditary nature of this superiority. In fact, as the author remarks in referring among other inquiries to Galton's work on *Hereditary Genius*, " in a State which justly prides itself on the equality of educational opportunity provided for children of every class . . . the ten-year-old child of the Californian labourer competes for high I.Q. rank no more successfully than the labourer's son competed for genius rank in Europe a hundred years ago."

These are briefly some of the conclusions of what is really only a preliminary work of inquiry; in general they help to confirm results obtained in similar inquiries carried out previously in the States and this country, and in addition break fresh ground. But one of the most important purposes that Dr. Terman has in view is to follow up the history of the subjects for at least ten years, and so by a comparison of promise and performance to get some idea of the usefulness of the scorings of intelligence and anthropometric tests as prognostic measures of the individual's future ability and value to the community of which he or she is a member. This is a field so far all too little explored. At present it seems only proposed to follow up the history of the gifted children. One hopes that it may be found possible to follow up a definite group of unselected children, for it is likely to be difficult to draw satisfactory conclusions from the history of the gifted only, for the 643 must inevitably dwindle as the years go on by loss of touch, etc. Although the boy with the average I.Q. score may be less likely to obtain academic distinction or find his way into *Who's Who*, it may well be that he will fill more successfully and usefully than his more gifted schoolfellow many fields of activity in his State or city.

We shall await the results of these further inquiries with much interest.

E S. P.

Teaching Science in the Schools. By ELLIOT R. DOWNING. [Pp. xiii + 185, with 12 illustrations.] (Chicago: at the University Press. Price 2 dollars.)

THIS is the second work in the series on the Teaching of Science published by the University of Chicago Press. It deals with the subject from a point of view quite different from that of Mr. Eikenberry, the author of the first book in the series. An historical review of the development of science teaching all over the world is followed by an exhaustive tabulated study of the present conditions of science teaching in American schools. The freedom that is given to American children in the choice of the subject matter of their education allows for interesting inquiry into the subjects offered in the High Schools and Universities. Further, it is interesting to note that in the selection of the subject matter of Science Teaching and in its manner of presentation, American teachers are moving rapidly in the direction of humanisation.

Our American colleagues too have a " flair " for experimental tests to determine the relative values of different methods of teaching. In spite of the complete ignoring of the personal equation that these involve, they almost invariably arrive at the same conclusions as our own educationalists working from accepted pedagogical principles of a more or less psychological character.

A long chapter on Science Teaching in Europe, with special reference to France and England, reveals some very striking comparisons. It is impossible not to feel some sense of satisfaction, however unworthy it may be, in the acknowledgment of the writer that the tuition in the English secondary schools is higher than it is in most first-class American Universities. It is only fair to recall that secondary education in America is far more widespread than with us. As the writer rather naively expresses it, referring to the free higher education, " we expose him to the contagion of an education as long as possible in the hope that he will take it."

The English teacher will be stimulated by reading this book, leading him, as it will, to new points of view of his work. W. C. B.

BOOKS RECEIVED

(Publishers are requested to notify prices)

Plane Curves of the Third Order. By Henry Seely White, Professor of Mathematics in Vassar College. Published with the co-operation of the National Research Council. Oxford University Press, 1925. (Pp. xii + 168.) Price 12*s.* 6*d.* net.

Leçons de Cinématique. Par Raoul Bricard. Tome i. Cinématique Théorique. Paris: Gauthier-Villars et Cie, 1926. (Pp. 336, with 117 figures.) Price 45 frs. net.

Leçons sur les Propriétés Extrémales et la Meilleure Approximation des Fonctions Analytiques d'une Variable Réelle. Par Serge Bernstein. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1926. (Pp. viii + 204.) Price 50 frs. net.

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La Détermination Calorimétrique de la Concentration des Ions Hydrogène. Par I. M. Kolthoff. Traduit sur la Troisième Édition Allemande avec l'Autorisation de l'Auteur par Edmond Vellinger. Paris: Gauthier-Villars et Cie, 55 Quai des Grands-Augustins, 1926. (Pp. xiv + 260.) Price 50 frs.

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INDEX TO VOL. XX (1925–1926)

PAGE

Abu'l-Quâsim Muhammad ibn Ahmad al-'Irâqi, " Book of Knowledge acquired Concerning the Cultivation of Gold " 156
Acoustic Vibrations by Single and Double Resonance. E. T. Paris 68
Advancement of Science, The South African Association for the 676
Agricultural Science, One Hundred Years of. G. E. Fussell 134
Allen, E. S. " Photo-Electricity " 716
American Indian, The 678
Andrade, E. N. da C. " Airs for the Hautbois and other Instruments " 369
Animal Nutrition. H. E. Woodman 429
Arber, A. " Monocotyledons " 724
Archæology, Prehistoric. J. R. Moir 586
Are the Continents Adrift ? G. W. Tyrrell 321
Associations of British Chemical Manufacturers. " British Chemicals, their Manufacturers and Uses " 722
Astbury, W. T. 538, 539
Aston, F. W. " Isotopes " 351
Astronomy. W. M. H. Greaves 7, 195, 565
Atwood, W. G., and A. A. Johnson. " Marine Structures " 165
Auerbach, F. " Modern Magnetics " 717
Aviation and Wireless, the Originators of 285

Backhurst, I. 154
Baly, E. C. C. " Spectroscopy " 176
Bates, L. F. 201, 350, 351, 392, 537, 568, 717, 718, 719
Bell, W. G. " The Great Plague in London in 1665 " 364
Bews, J. W. " Plant Forms and their Evolution in South Africa " 357
Billroth, T. " Medical Sciences in the German Universities " 550
Biochemistry. R. K. Cannan 26, 405
Biology, The Borders of. J. H. Woodger 326
Borel, E. " Traité des Calcul des Probabilités et de ses Applications " 712
Botany, E. J. Salisbury 217, 588
Bower, F. O. " Plants and Man " 358
Brady, O. L. 157, 205
Brenchley, W. E. 543, 726
Brooks, C. F. " Why the Weather ? " 556
Brown, W. C. 165, 355, 371, 546, 552, 556, 736
Brown, W. H. " A Textbook of General Botany " 541
Browne, A. D. " Tables and Charts for the Use of Engineers and Others " 714
Bryant, V. S. 138
Burt, E. Z. " The Metaphysical Foundations of Modern Science " 367

Cameron, A. E. 92
Cannan, H. G. 728

PAGE
Cannan, R. K. 26, 405, 731
Carr-Saunders, A. M. "Population" 734
Castle, W. E. "Genetics and Eugenics" 168
Chemical Age Chemical Dictionary, The 157
Chemistry, Organic. O. L. Brady 205
Chemistry, Physical. W. E. Garner 31, 400
Cheyne, W. W. "Lister and His Achievement" 548
Chimpanzees, Intelligence of. J. A. Thomson 533
Cole, G. A. J. "Handbook of the Geology of Ireland" 356
Coleridge as a Philosophical Biologist. J. Needham 692
Colour, The Industrial Measurement of. W. G. Raffé 662
Colour in Industry, The Scientific Value of. W. G. Raffé 256
Conger, G. P. "A Course in Philosophy" 733
Continents Adrift? Are the. G. W. Tyrrell 512
Coolidge, J. L. "An Introduction to Mathematical Probability" 344
Coursey, P. R. 366
Crowther, W. E. 125
Cullis, W. C. 362, 363, 364, 730
Curtis, W. E. 176
Cushing, H. "The Life of Sir William Osler" 150
Cutler, D. W. "Evolution, Heredity, and Variation" 546
Cutting, E. M. 159, 160, 357, 724
Czech Contributions to Chemical Science, Some. J. G. E. Druce 308

D'Ainvelle, J. V. "L'Origine Tourbillonnaire de l'Atome" 351
Darwinist, The Religion of a. R. R. 123
Davidson, J. 165, 225, 362, 594
Davidge, H. P. 551
Dawes, C. L. "Industrial Electricity" 365
Dawson, W. R. 109
Dell, J. A. "Animals in the Making" 165
Denton, F. M. "Relativity and Common Sense" 153
Downing, E. R. "Teaching Science in the Schools" 736
Dr. Gye and Cancer. J. E. McCartney 284
Drake-Brockman, R. E. 174, 547, 548, 556
Druce, J. G. F. 308, 540, 690
Dukes, C. "The Bacteriology of Food" 548
Dvi-Manganese. J. G. F. Druce 690

Eagle, A. "Fourier's Theorem and Harmonic Analysis for Physicists and Engineers" 712
Eames, A. J. "An Introduction to Plant Anatomy" 725
Education. A. E. Heath 237
Education in Ancient Egypt. W. R. Lawson 109
Education in East Africa. Report of the Educational Commission of the Phelps-Stokes Fund to East Africa 556
Edwards, D. L. 603
Einstein, A. "Quatre Conférences sur la Théorie de la Relativité" 153
Electricity through Discharge Tubes at Low Pressure, The Passage of. R. Whiddington 620
Emerson, P. "Soil Characteristics" 726
England and Ireland 683
Entomology. J. Davidson. 225, 594

PAGE
Ethics of Birth-control, Public Discussions on the 682
Evans, H. J. 722, 729, 730
Evers, N. " The Chemistry of Drugs " 720
Evolution in the Light of Modern Knowledge. A Collective Work . 543
Evolution, The Physics of 337

Farrow, E. P. " Plant Life on East Anglian Heaths " 159
Findlay, A. " Physical Chemistry for Students of Medicine " . . 155
Fisher, J. W. 153, 154
Fisher, R. A. " Statistical Methods for Research Workers " . . 733
Flexner, A. " Medical Education " 549
Flint, Colour and other Changes in the Flaked Surfaces of. J. R. Moir 249
Fluid Masses, Forms of Equilibrium of. W. E. Crowther 125
Forsyth, C. E. " Mathematical Analysis of Statistics " 176
Fourneau, E. " Organic Medicaments and their Preparation " . . 729
Frazer, E. A. 546
Fussell, G. E. 134

Garner, T. L. 721, 722
Garner, W. E. 31, 155, 352, 353, 354, 400
Geology. G. W. Tyrrell. 36, 211, 408, 577
Geology, The Progress of London. S. W. Wooldridge 517
Geological Science, The Contribution of America to. G. W. Tyrrell . 146
Geological Survey. " Maps and Memoirs on the London District " . 517
Greaves, W. M. H. 7, 195, 565
Gregory, J. C. 298
Goodrich, E. S. " Living Organisms " 326
Gunther, R. T. " Historic Instruments for the Advancement of Science " 553
Guye, C. E. " Physico-chemical Evolution " 155

Haas, P. 155, 156, 355, 720, 721
Hadamard, J. " Lectures on Cauchy's Problem " 345
Haddon, A. C. " The Races of Man and their Distribution " . . 171
Hammond, J. 232
Harrow School Register, The 682
Hart, I. B. " The Mechanical Investigations of Leonardo da Vinci " . 370
Hart, I. B. 368, 370, 554
Hartland, E. S. " Primitive Law " 173
Haskins, C. H. " Studies in the History of Mediæval Science " . . 370
Hatschek, E. " The Foundations of Colloid Chemistry " 352
Hazeltine, L. A. " Electrical Engineering " 366
Heath, A. E. 237
Heaton, N. " Volatile Solvents and Thinners " 721
Herdman Scholarship, A. 683
Herzfeld, K. F. " Müller-Pouillet's *Lehrbuch der Physik* " . . . 718
Hickson, S. J. " An Introduction to the Study of Recent Corals " . 166
Higgins, S. H. " An History of Bleaching " 253
Hill, L. " Health and Environment " 546
Hogben, L. T. " An Introduction to Recent Advances in Comparative Physiology " 364
Holman, R. M., and W. W. Robbins. " A Textbook of General Botany " 158

PAGE

Homes, S. J. "Louis Pasteur" . . . 729
Holmyard, E. J. "Chemistry to the Time of Dalton" . . . 355
Hosmer, G. L. "Practical Astronomy" . . . 715
Houstoun, R. A. "Intermediate Light" . . . 350
Houstoun, R. A. "A Treatise on Light" . . . 536
Huntingdon, E. "Civilisation and Climate" . . . 552
Hydrogen Ion Concentration and Growth. W. H. Pearsall . . . 58

Imms, A. D. "A General Text of Entomology" . . . 164
Indian Unrest, The Psychology of. W. G. King . . . 523
Individuality in Biology, some Remarks on the Conception of. E. P. Mumford . . . 83
Industrial Institute, The . . . 120, 288
Information-Bureaux Conference . . . 501
Innes, J. . . . 50
Invertebrates, The Digestion of Cellulose by. C. M. Yonge . . . 242
Irwin, J. T. "Oscillographs" . . . 552

Jackson, A. N. . . . 365, 366, 367
Jaeger, F. M. "Le Principe de Symétrie et ses Applications" . . . 538
Jeffery, E. C. "Coal and Civilisation" . . . 541
Johnstone, J. . . . 166, 167
Jolley, L. B. W. "Summation of Series" . . . 535
Jones, D. F. "Genetics in Plant and Animal Improvement" . . . 543
Jones, W. D., and D. S. Whittlesey. "An Introduction to Economic Geography" . . . 554
Jones, L. L. R., and P. W. Bryan. "North America" . . . 177

Kaye, G. W. C., and T. H. Laby. "Four-figure Mathematical Tables" 535
Keith, A. "The Engines of the Human Body" . . . 550
Keyserling, H. "Travel Diary of a Philosopher" . . . 732
King, W. G. . . . 523
Koffka, K. "The Growth of the Mind" . . . 369
Köhler, W. "The Mentality of Apes" . . . 533
Kretschmer, E. "Physique and Character" . . . 179

Lafay, A. "Notations et Formules Vectorielles" . . . 342
Laue, M. v. and others. "Handbuch der Radiologie" . . . 535
Leathem, J. G. "Elements of the Mathematical Theory of Units" 343
Lévy, P. "Calcul des Probabilités" . . . 712
Lewent, L. "Conformal Representation" . . . 344
Lipschutz, A. "The Internal Secretions of the Sex Glands" . . . 163
Lodge, O. "Electric Precipitation" . . . 717
Lodge, O. "Atoms and Rays" . . . 348
Loeb, J. "Regeneration" . . . 155
Lotka, A. J. "The Elements of Physical Biology" . . . 337
Ludford, R. J. . . . 221, 591

MacBride, E. W. . . . 461
McCartney, J. E. . . . 284
MacCurdy, G. G. "Human Origins" . . . 703
Machin, A. "The Ascent of Man" . . . 727
MacLaurin, C. "Mere Mortals" . . . 731

Maiden Speech, A new kind of 285
Mammalian Reproductory Physiology, Recent Discoveries in . . 675
Mason, F. A. 354, 356
Mathematical Formulas became True, When certain. G. A. Miller . 436
Mathematics, Pure. F. P. White 1, 189, 377
Matisse, G. " Mouvement Scientifique Contemporain en France " . 718
Medical Councils 123
Medical Discovery, The Encouragement of. Sir R. Ross . . . 513
Mellor, J. W. " Modern Inorganic Chemistry " 354
Merrill, G. P. " The First Hundred Years of American Geology " . 146
Meteorology. E. V. Newnham 12, 385
Millais, J. G. " Far Away up the Nile " 174
Miller, G. A. 342, 436
Milne, L. " The Home of an Eastern Clan " 172
Modern Miracles 285
Moir, J. R. 249, 586
Morgan, T. H. " Evolution and Genetics " 728
Morrell, R. S. " The Chemistry of Drying Oils " 721
Morse, A. H. " Radio: Beam and Broadcast " 365
Mosquito-control, The Importance of. Sir R. Ross 481
Mosquito-theory of Malaria and the late Prof. G. B. Grassi. Sir R. Ross 311
Moskowski, A. " The Isles of Wisdom " 368
Moss, R. " Life after Death in Oceania and the Malay Archipelago " 554
Motor-tyres and Reclaimed Rubber 680
Mumford, E. P. 83
Murray, M. A. 555

Neaverson, E. " Ammonites from the Upper Kimmeridge Clay " . 722
Needham, J. 692
Newman, F. H. " Production and Measurement of Low Pressures " . 154
Newman, H. H. " Outlines of General Zoology " . 359, 556
Newnham, E. V. 12, 175, 385
Newton, E. W. 439
Norman Bridge Laboratory of Physics, The. E. C. Watson . . 273
Notes and News 126, 288, 503, 683

Obermaier, H. " Fossil Man in Spain " 169
Oldham, R. D. 487
Olivier, C. P. " Meteors " 715
On All-fours 287
Onslow, M. W. " The Anthocyanin Pigments of Plants " . . . 354
Optical Convention for 1926, The 677
Osler, William, Sir R. R. 150

Parasitism in Evolution. Sir A. E. Shipley 637
Paris, E. T. 68
Pearl, R. " Studies in Human Biology ". 177
Pearsall, W. H. 58
Pearson, E. S. 177, 734, 735, 736
Pearson, T. G. " Birds of America " 361
Pearson, W. A., and J. S. Hepburn. " Physiological Clinical Chemistry" 730
Pedology. G. W. Robinson 423
Personal Recollections, Sir A. E. Shipley 497

PAGE
Phillips, H. B. " Differential Equations " . . . 711
Physical Process, The Animate Model of. J. C. Gregory . . . 298
Physics, L. F. Bates . . . 201, 392, 568
Physics, J. Rice . . . 16
Physiology of Reproduction. J. Hammond . . . 282
Physiology, Pathology and Epidemiology . . . 500
Pidduck, F. B. " A Treatise on Electricity " . . . 350
Plant Physiology. W. Stiles . . . 44, 417
Plimmer, R. H. A. " Food and Health " . . . 731
Ponder, E. " The Erythrocite and the Action of Simple Hæmolysins " 730
Practical Application of the Sciences, The . . . 122
Prehistory, The Progress of, β_2 . . . 703
Premier Conseil de Chimie tenu à Bruxelles, 1922 . . . 352
Prickly Pear in Australia, The . . . 679
Prince, M. " Problems of Personality " . . . 368
Professor E. W. MacBride, F.R.S. . . . 675

Raffé, W. G. . . . 256, 662
Recapitulation Theory, The. E. W. MacBride . . . 461
Reese, A. M. " Outlines of Economic Zoology " . . . 162
Religion and Science in Russia of To-day, The Position of . . . 681
Research, Government and . . . 120
Rhone Delta, The Post-Roman History of the. R. D. Oldham . . . 487
Rice, J. . . . 16
Richardson, E. G. " Oscillographs " . . . 552
Roaf, E. E. " A Textbook of Physiology " . . . 363
Robinson, G. W. . . . 423
Rolfe, R. T. and F. W. " The Romance of the Fungus World " . 358
Ronaldshay, Earl of. " The Heart of Âryavârta " . . . 523
Rosengarten, W. " Choosing your Life-work " . . . 552
Ross, Sir R. . . 122, 123, 150, 311, 364, 368, 369, 481, 513, 535, 732, 733
Rowan, W. . . . 361
Russell, A. S. " An Introduction to the Chemistry of Radio-active Substances " . . . 539

S. T. Coleridge as a Philosophical Biologist. J. Needham. . . . 692
Salisbury, E. J. . 158, 161, 162, 217, 358, 359, 542, 588, 724, 725, 726
Sanderson at Oundle and Preparatory Education, V. S. Bryant . . 138
Savory, T. H. . . . 475
Schotz, S. P. " Synthetic Organic Compounds " . . . 157
Schweitzer, A. " On the Edge of the Primeval Forest " . . . 174
Scientific Periodicals . . . 286
Shackleton, M. R. . . . 178, 553, 554
Shand, S. J. " Useful Aspects of Geology " . . . 540
Shearcroft, W. F. F. " Matter, Man, and Mind " . . . 733
Shearer, G. . . . 450
Shipley, A. E. . . . 497, 637
Shrubsall, F. C. . . . 370
Siegbahn, M. " The Spectroscopy of X-rays " . . . 537
Simon, A. L. . . . 268
Sinnott, E. W., and L. C. Dunn. " Principles and Genetics " . . . 726
Smallpox, The Flare-phenomenon in. R. R. . . . 122
Smith, D. E. " History of Mathematics " . . . 340
Smith, G. M., and others. " A Textbook of General Botany " . . 158
Smith, J. H. . . . 349, 350, 351

PAGE
Smith, W. R. "In Southern Seas" . . . 178
Snodgrass, R. E. "Anatomy and Physiology of the Honey Bee" . 362
Soil Insects. A. E. Cameron . . . 92
Solidity, The Measurement of. J. Innes . . . 50
Southerne, L. "Electricity and the Structure of Matter" . . 539
Spiders, Evolution in. T. H. Savory . . . 475
Spielmann, P. E. "The Constituents of Coal Tar" . . . 355
Spielmann, P. E. "Bituminous Substances" . . . 355
Spitsbergen Papers . . . 725
Spurious Evidence . . . 124
Stamp, L. D. "The Vegetation of Burma from an Ecological Standpoint" . . . 542
Starr, O. "Lamarck-Darwinism and Dental Disease" . . . 167
Stellar Parallax, The Determination of. D. L. Edwards . . . 603
Stenhouse, E. "A Class Book of Botany" . . . 723
Stevens, W. C. "Plant Anatomy" . . . 161
Stiles, W. . . . 44, 417
Stiles, W. "Photo-Synthesis" . . . 720
Suess, E. "The Face of the Earth" . . . 356
Sun, Observations of Systematic Movements within the. H. W. Newton . . . 439
Swain, G. F. "Structural Engineering" . . . 551

Taylor, E. S. "A Treatise on Physical Chemistry" . . . 353
Terman, L. M. "Genetic Studies of Genius" . . . 735
Thirst of Man, The. A. L. Simon . . . 268
Thomas, M. . . . 545
Thomson, J. A. . . . 533
Thomson, J. A. "Concerning Evolutions" . . . 545
Thorburn, A. "British Birds" . . . 360
Thornton, H. G. . . . 549
Thorpe, M. R. "Organic Adaptation to Environment" . . . 160
To Dazzle, or not to Dazzle . . . 680
Troup, S. . . . 543
Tyrrell, G. W. . . . 36, 146, 211, 321, 356, 357, 408, 512, 540, 541, 577

Underhill, D. "Magnets" . . . 367

Valiron, C., et P. Appell. "Mémorial des Sciences Mathématiques" . 714
Verney . . . 549, 550, 551
Verriest, G. "Cours de Mathématiques Générales" . . . 714
Vincent, S. "Internal Secretion and the Ductless Glands" . . . 362
Visher, S. S. "Climatic Laws" . . . 175
Voronoff, S. "Rejuvenating by Grafting" . . . 362

Warming, E. "Œcology of Plants" . . . 357
Watson, E. C. . . . 273
Wegener, A. "The Origin of Continents and Oceans" . . . 321
Weir, J. . . . 723, 729
Westaway, F. W. "Scientific Method" . . . 371
Whiddington, R. . . . 620
White, F. P. . 1, 189, 343, 344, 345, 348, 377, 711, 712, 713, 714, 715

Williams, L. "The Science and Art of Living" 553
Wilson, W. "Small Electric Generating Sets" 365
Winter Thunderstorms 679
Woodger, J. H. 163, 164, 326, 360
Woodman, H. E. 449
Wolf, A. 371, 733
Wooldridge, S. W. 517
Wright, J. A. S. 168
Wyckoff, R. W. G. "The Structure of Crystals" 349

X-Ray Analysis of Organic Compounds, The. G. Shearer . . . 450

Yerkes, M., and B. W. Learned. "Chimpanzee Intelligence" . . 533
Yonge, C. M. 242

Zittel, K. A. von. "Textbook of Palæontology" 729
Zoology. R. J. Ludford 221, 591

I. A. R. I. 75

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